Aeroplane Maintenance and Operation Series, Volume 4

AIRSCREWS

(PART 1)

AEROPLANE MAINTENANCE AND OPERATION SERIES

Compiled under the General Editorship of E. MOLLOY

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Aeroplane Maintenance and Operation Series, Volume 4

AIRSCREWS

(PART 1)

DEALING WITH THE MAINTENANCE AND REPAIR OF THE DE HAVILLAND CONTROLLABLE-PITCH AIRSCREWS AND HYDROMATIC AIRSCREWS

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COMPILED BY A PANEL OF EXPERTS

WITH NINETY-NINE ILLUSTRATIONS

GEORGE NEWNES LIMITED
Tower House, Southampton Street, Strand
LONDON, W.C.2

PRINTED IN GREAT BRITAIN BY HAZELL, WATSON & VINEY, LTD., LONDON AND AYLESBURY

PREFACE

A GOOD "take-off" is the *sine qua non* of a happy landing. In these days when long-distance flying frequently renders it necessary for very heavy loads of fuel to be carried, a good "take off" can only be ensured by making provisions such that the engine or engines upon which the "take off" depends are able to work under favourable conditions during the "take off" period.

One of the most important factors for ensuring these favourable conditions is the variable-pitch airscrew. The present volume has been devoted to the types of variable-pitch airscrews manufactured by the de Havilland Company. Other types, such as the Rotol, will, it is hoped, be dealt with in similar detail in a later volume of this series.

As will be apparent from the serial title "Aeroplane Maintenance and Operation," the primary object of each volume in this series is to provide in a convenient form information calculated to be of immediate use to ground engineers and others who are responsible for the maintenance and servicing of aeroplanes.

As has already been indicated, the function of the controllable-pitch airscrew is to enable the engine to develop its maximum horse-power, both for "take off" and for flying at the rated altitude. It may, in fact, be said that the controllable-pitch airscrew performs the same function on an aeroplane as does the gearbox on a motor-car. Every reader will readily appreciate that a single-geared car would be either very difficult to start without stalling, or else it would be severely limited in its top-speed performance. The same applies, though perhaps to a less degree, in the case of an aeroplane with a fixed-pitch airscrew.

In the present treatise will be found a clear description of the underlying principles upon which the controllable-pitch airscrew operates. An understanding of these underlying principles is necessary in order that the overhauling and adjustment can be carried out with intelligence and efficiency. After this preliminary explanation, detailed instructions are given for the removing and dismantling of the de Havilland controllable-pitch airscrew. These instructions have been illustrated by a unique series of action pictures, which have been specially staged to show the operations involved.

Special attention has been devoted to the correct method of installing this type of airscrew, and also the testing and adjustment to ensure maximum efficiency.

One of the latest developments of the controllable-pitch airscrew

is the hydromatic airscrew, which has the special feature of a feathering position for the blades, so that when desired the airscrew blades can be brought into such a position that they are in line with the forward direction of the motion of the aeroplane.

Being able to feather is particularly useful on multi-engined aeroplanes, because in the event of serious mechanical trouble, such as a broken oil pipe, the act of fully feathering (after switching the ignition off) stops the engine, and as the blades are edge on to the wind, they cannot "windmill," and so cause further damage to the engine.

The electrical control, which is used for this type of airscrew, forms the subject of a separate chapter. Although the present work is not designed specifically for pilots, it was thought desirable to include at the end some notes dealing with the correct method of operating the controllable-pitch airscrew from the pilots' point of view.

E. W. K

E. M.

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AIRSCREWS

THE DE HAVILLAND CONTROLLABLE-PITCH AIRSCREW

WITH NOTES ON THE HAMILTON HYDROMATIC AIRSCREW

THE controllable-pitch airscrew is a type in which the angular setting of the blades can be controlled while in flight. The blades are adjustable in both high- and low-pitch positions, thus enabling the engine to develop its maximum horsepower both for take-off and for flying at rated altitude. In many respects the controllable-pitch airscrew serves the aeroplane in much the same way as a gearbox serves a motor-car.

In principle the design of all variable-pitch airscrews is similar. They all provide rigid blades which are rotated about their centre lines in order to change pitch. An outer member called the barrel envelops the blade roots and is designed to absorb the centrifugal pull of the blades when the airscrew is rotating.

Change from High to Low Pitch

The airscrew is mounted on the forward end of the airscrew-shaft and the change from high to low pitch is effected by the hydraulic pressure from the engine oil system, and by counterweights which apply centrifugal force to move the blades.

In flight the natural tendency of the blades is to take up the high-pitch position under the centrifugal pull of the counterweights which is always in being when the airscrew is rotating; and the low-pitch position is attained by admitting oil under pressure to a cylinder which then moves along a fixed piston, and through the agency of a cam motion forces the blades to take up the low-pitch position against the pull of the counterweights.

When the pressure is released, the blades are returned to high-pitch position and the oil in the cylinder is returned to the crankcase under the pull of the counterweights.

Operation and Control

The two positions of the control cock or piston valve are " oil gallery to cylinder " and " cylinder to sump," and movement is effected from one

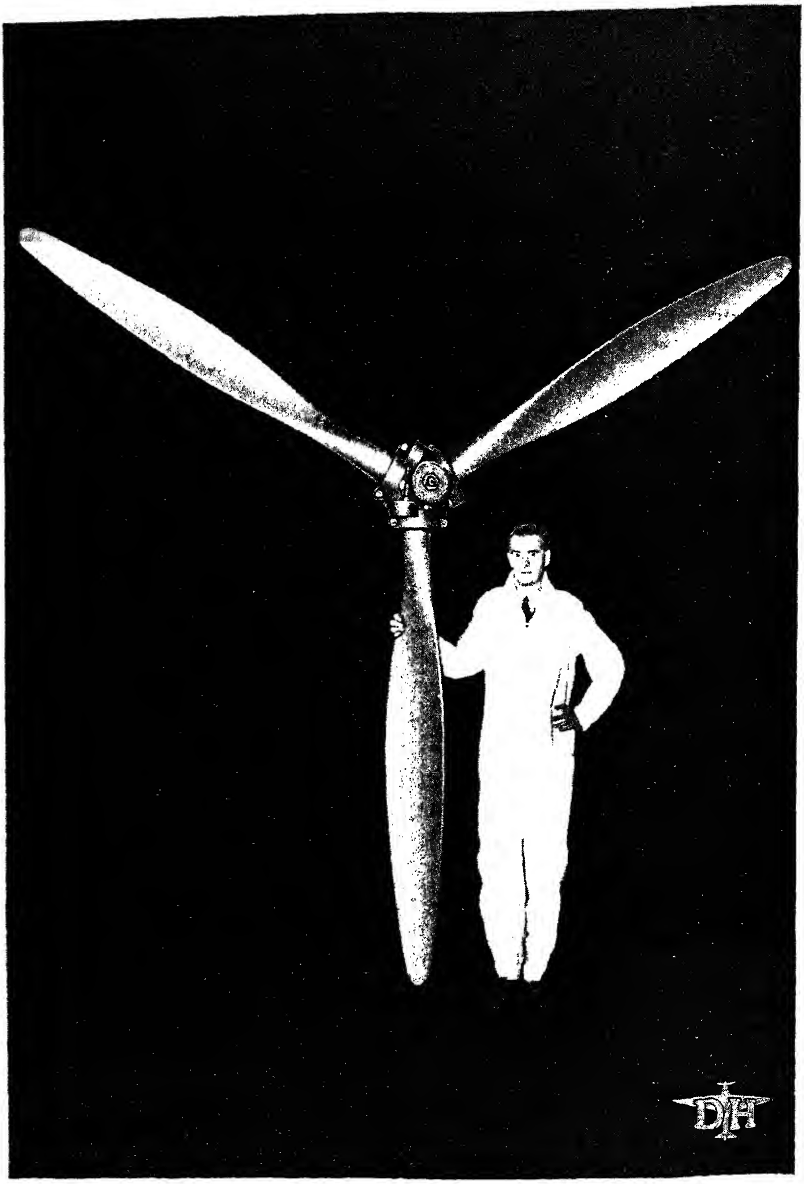


Fig. 1.—THE DE HAVILLAND CONTROLLABLE-PITCH AIRSCREW WITH 20° PITCH RANGE

position to the other from the pilot's cockpit by means of an approved type of control. The conventional method of installing these controls is to fit them so that they "follow the throttle," i.e. they are pushed forward for high pitch and drawn back for low pitch.

The time required to change pitch varies with each installation, and also in accordance with a number of factors relating to the conditions of flight obtaining, but in the most tardy cases it is never more than a few seconds.

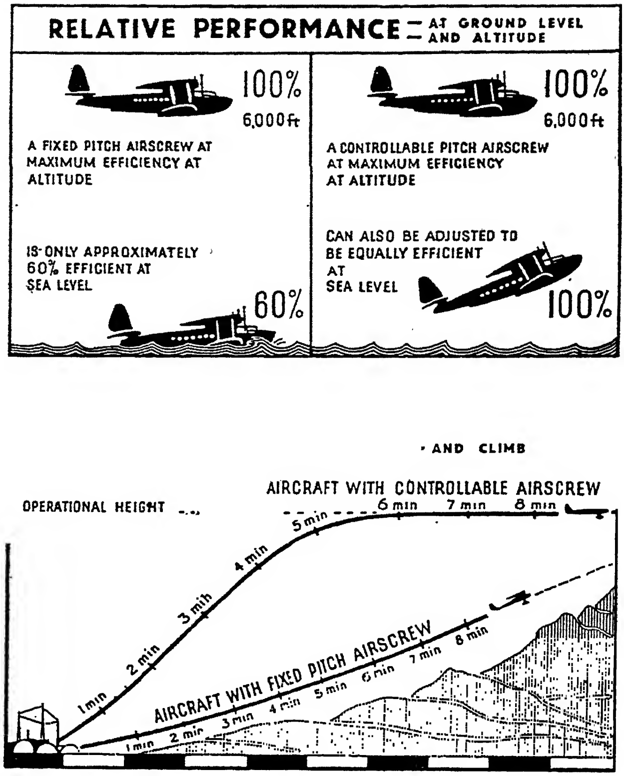


Fig. 2.—RELATIVE PERFORMANCE OF FIXED-PITCH AND CONTROLLABLE-PITCH AIRSCREWS

Performance

The accompanying diagrams show the relative performance of fixed-pitch and controllable-pitch airscrews at ground level and altitude, and during take-off and climb.

The Hydromatic Airscrew

The most recent development of the controllable-pitch type of airscrew is the hydromatic airscrew, which has been introduced to meet with certain requirements.

The increasing practice of making power descents from high altitude, by which means some of the time and fuel expended in climbing to clear high obstacles or to take advantage of favourable winds may be recovered by a long medium power descent at high speed, usually requires a coarser pitch on the blades than is available in an airscrew of even 20° pitch range.

Furthermore, increasing attention is being directed to the necessity for dealing with engine failure, which, though markedly on the

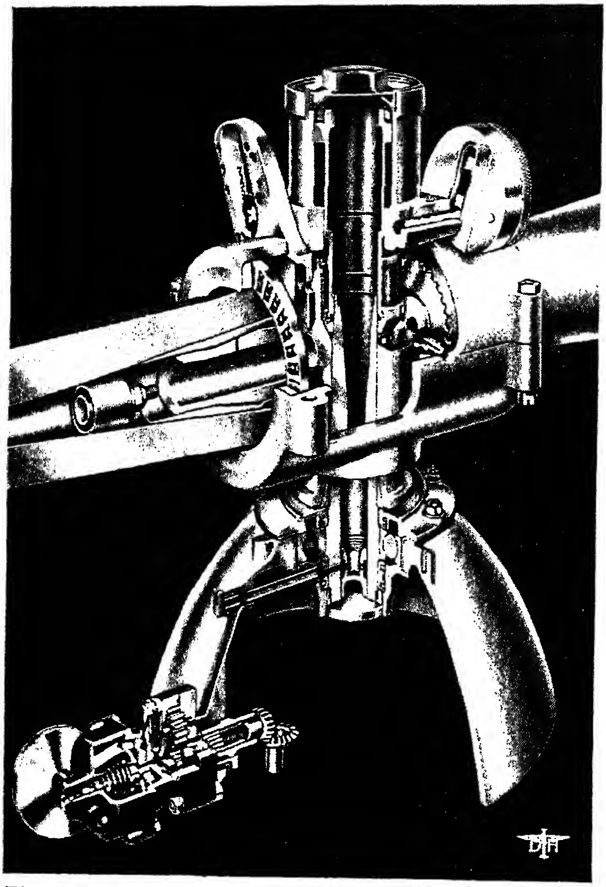


Fig. 3.—Controllable-pitch airscrew and constant-speed governor installation in part section

decrease as a percentage, has nevertheless increased in importance due to the rapid multiplication of fast air-line traffic which must fly to a schedule and maintain the highest possible record of safety.

Safeguarding Engine after Failure

The problem in this second case is chiefly one of safeguarding the engine after failure, since a controllable-pitch airscrew windmilling freely in coarse pitch imposes only about one-fifth of the drag of the same airscrew held stationary.

Although it can never be safe or satisfactory to allow an engine which has failed in flight to continue rotating, hitherto the only alternative has been to brake the airscrew shaft and so force the engine to rest, thereby increasing the drag of the airscrew very considerably.

Such a brake is easy to fit, but from the few instances in which the provision has been made, it is clear that the great majority of operators regard the increased drag as the greater evil.

Some criticism has been levelled at the controllable-pitch airscrew, on the grounds that maintenance is somewhat difficult, especially where spinners are fitted ; that the internal mechanism is exposed to atmosphere and suffers from rain, salt spray, dust, and the infiltration generally of deleterious matter, and that with unlimited supplies of oil actually within the airscrew it remains necessary to effect lubrication by hand, at more or less irregular intervals and often in circumstances of such difficulty that it is liable to be skimped or omitted altogether.

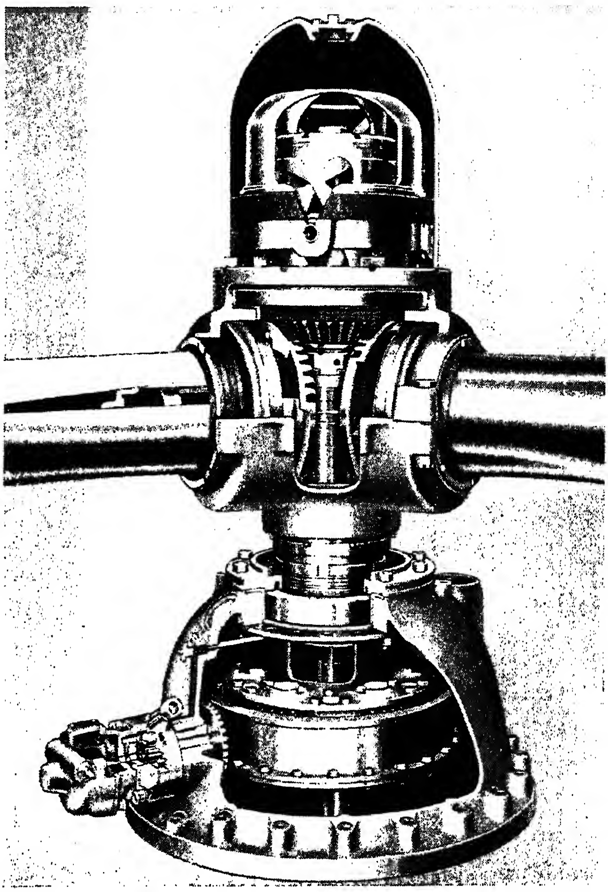


Fig. 4.—Hamilton hydromatic airscrew and governor in part section

In point of fact, these difficulties are less a criticism of the airscrew than of the service by which it is maintained, because the airscrew usually requires less extensive and no more frequent attention than the engine. A very large number of airscrews have now demonstrated an ability to give thousands of hours of trouble-free service with a minimum of regular attention.

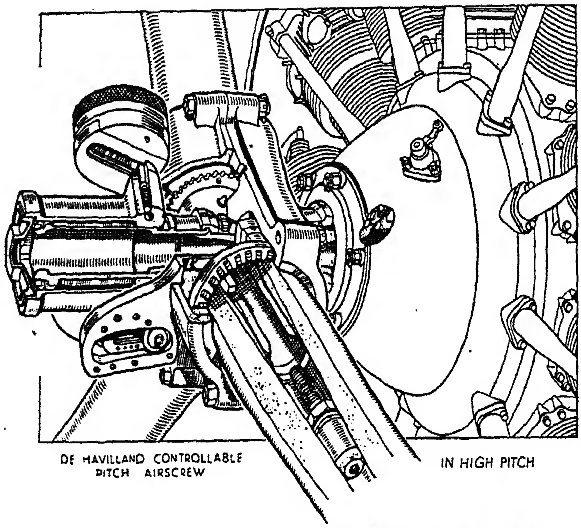
A study of these requirements, however, revealed that they could not be incorporated in the counterweight-type airscrew except by radical modification, and Hamilton Standard therefore approached the problem by redesigning the airscrew around the proved and characteristic features of the two-pitch and constant-speed airscrews whilst retaining their functions and safety provisions.

This airscrew, the Hamilton Hydromatic, has already been adopted by all the principal air lines in the United States of America, and the British version building under licence is now in production by the de Havilland Aircraft Co. Ltd. in England.

Increased Range of Blade Angle

In normal operation the airscrew functions as a constant-speed airscrew, but it possesses an increased range of blade angle to conform to the requirements of modern high-performance aeroplanes.

Further, however, the angles of the blades can be increased to a position in which their chords are edge-on to the line of flight, and whilst



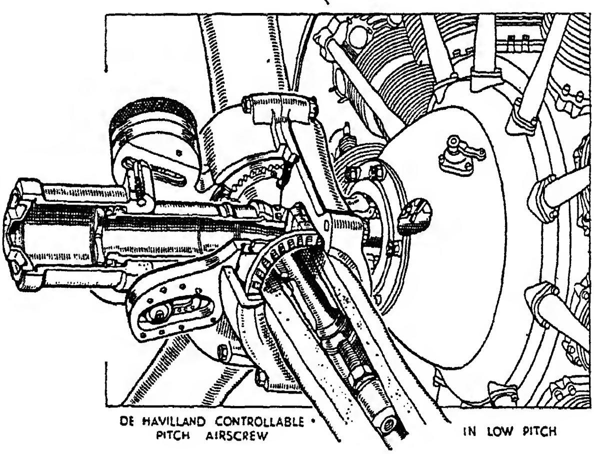


Fig. 5.—THREE-BLADED CONTROLLABLE-PITCH AIRSCREW IN HIGH- AND LOW-PITCH POSITION

in this position the blades act as paddles, producing no thrust and quickly bringing a defective engine to rest.

This feathering function, as it is called, is accomplished in a very few moments, and a defective engine can thus be shut down and stopped, usually before any serious damage is done. Moreover, in the feathered position the blades offer the least possible drag and permit the aircraft to proceed with the other engine or engines in operation with a minimum loss of performance.

Improvement in Ceiling

The improvement in ceiling of a twin-engined aircraft with one airscrew feathered as compared to the same airscrew stopped but not feathered is often as much as 2,000 ft. and is therefore a factor of considerable importance, whilst the control of the aircraft with a feathered airscrew is also better, because there is less disturbance of the airflow over the wing surfaces.

Further advantages of the feathering airscrew, which will henceforward be available in all large aircraft, are the opportunity of stopping the engine for the purpose of carrying out repairs or adjustments and the possibility of securing enhanced engine life and fuel economy by stopping one or more engines after reaching operating altitude, which will doubtless be fully explored.

Construction of the Hydromatic Airscrew

The construction of the hydromatic airscrew is similar to the counterweight type in so far as a spider, barrel, barrel packing blocks, blades, blade bushings, and thrust races have been provided to perform the same functions as in the earlier design.

It has, however, a separate pitch-change mechanism of new design, which has the further advantage of being interchangeable between airscrews as a separate assembly. This is known as the dome assembly, which also functions as a spinner.

Having discussed briefly the principle of the controllable-pitch airscrew, we now deal with the complete overhaul of this component. A later article deals fully with the operation and installation.

COMPLETE OVERHAUL OF THE DE HAVILLAND CONTROLLABLE-PITCH AIRSCREW

When complete overhaul of the airscrew is due, the History Sheet of the airscrew must be produced and compared with the up-to-date list of modifications authorised in order to determine what work is required in addition to that necessary to make good wear and tear.

TO REMOVE THE AIRSCREW FROM THE AIRSCREW SHAFT

(1) Disengage spring draw-bolt nut lock wire and remove spring draw-bolt nut and joint washer.

(2) Remove cylinder-head lock ring and remove the cylinder head, using the special spanner provided.

(3) Unlock and remove the sixteen piston-head securing screws, together with piston head and spring draw-bolt packing washer.

(4) Remove the spring draw bolt, spring draw-bolt bucket, and the two spiral springs as one unit.

(5) Disengage the piston lock ring by removing the securing split pins. Unscrew the piston, using the special box spanner and tommy bar provided. This operation will pull the airscrew off the rear cone, and as soon as it is felt to be loose, the weight should be taken by means of a rope sling already reeved round two of the blades, when the airscrew may be pulled clear and lowered. The third blade of a three-bladed airscrew is used as a lever to turn the airscrew into the horizontal position prior to lowering on to the stripping bench.

TO DISMANTLE THE AIRSCREW

(1) Lower the airscrew on a suitable sleeve and mandrel fixed perpendicularly in the assembling base plate.

Note.—The cylinder head, draw bolt, springs, etc., have already been

Fig. 6.—The Hamilton hydromatic airscrew

Before dismantling, the airscrew is hoisted up and the oil drained out as shown. This makes for cleaner working. We are indebted to British Airways Ltd. for facilities for staging this and many of the action photographs accompanying this section.

removed in dismantling the airscrew from the airscrew shaft.

(2) Extract split pins and locking pins and unscrew counterweight caps. Check and record the blade settings indicated on the lead fillings in the counterweight, and by the scale reading of the adjusting nuts, and remove adjusting screw assemblies.

(3) Remove the screws holding counterweights to brackets, and tap the counterweights off the faces of the brackets.

(4) Remove counterweight bearing-shaft cotter pins from cylinder.

(5) Unscrew and remove counterweight bearing shafts and counterweight bearing-shaft races, spacers, and thrust washers.

(6) Disengage spider snap ring by inserting two screwdrivers in grooves provided and compressing snap ring.

(7) Lift cylinder, piston, snap ring, cone, and lock ring together. It is desirable and convenient at this stage to check the torque loading of the blades, as an indication of the loading to be expected when the airscrew is again assembled. The method of carrying out this check is given in later instructions.

(8) Remove barrel bolts.

(9) Wrap blade shanks and insert strips of cardboard between the outer bearing races and the blade shank to prevent chafing by the thrust bearings during and after removal of the barrel.

(10) Separate the halves of the barrel by using a lever in the slots provided on the joint face on the rear half, and then by lifting the top and lowering the bottom.

(11) Ensure that blades, bearing races, and roller cages are marked in order that they may be reassembled in their correct relative positions.

(12) Remove the blades from the spider.

Fig. 7.—REMOVING THE BARREL AND SPIDER SEAL

(13) Note the location of the index pins in the counterweight brackets, and check with the figures stamped on the lead plug in the counterweight. Remove counterweight brackets.

(14) Remove shim packs and packing plates from spider.

The dismantling, inspection, and assembly of all present types of the de Havilland controllable-pitch airscrew are essentially the same, and aeroplane operating companies having facilities and undertaking their own servicing will require the following equipment:

A de Havilland-type splined sleeve to fit each type of airscrew hub with rear cone or splines, and threads for the piston. The arbor should have a hole through it accurately bored and ground for inserting the balancing mandrel.

A suitable surface plate for checking blade angles, and a mandrel and base on which the splined sleeve may be mounted.

This equipment, if not ordered from the manufacturers, must be carefully made and finished so that the blade angles may be checked accurately.

To ensure satisfactory operation of the airscrew, it is most important that it be assembled with all parts in their respective positions in order

Fig. 8.—Cutting locking wires on slinger ring

that the adjustments which have been made to procure the necessary fits and clearances shall not upset the balance of the airscrew or interfere with its operation when installed. For this reason, the blade apertures in the barrel, the arms of the spider, the blades, the counterweight brackets and caps, barrel bolts, counterweight bearing shafts, etc., are all identified with each other and matched up in their various positions by the following system of numbering :

On a two-bladed airscrew when lying in a horizontal position the whole of the items on one side of the hub are marked " No. 1 " and those on the opposite side " No. 2." In the case of a three-bladed airscrew all items are marked " Nos. 1, 2, 3 " in rotation to show their relation to each blade. It is of primary importance that all these numbers should be matched up and assembled as indicated by these markings.

Another point to observe carefully is the radial positioning of the thrust race relative to the blade root. An examination of the peripheries of the blade boss and the inner thrust race will show marks " 0." When assembling the blades into the barrel, these marks must be kept exactly in line, and care should be taken to ensure that they remain in line when drawing together the halves of the barrel.

The verification of this system and these markings on the airscrew

during stripping may save a lot of time and trouble on reassembly, and should not therefore be neglected.

INSPECTION OF PARTS AND RECONDITIONING

The inspection of the airscrew components should be carried out, first, to detail any damage which may have occurred, and secondly, to check the extent of wear and tear against the Schedule of Fits and Clearances which is given at the end of this section.

(1) The Counterweight Bracket

This should be very carefully tapped off the blade bushings, using a hide mallet or a soft metal punch—it must not be prised off against the chamfer on the blade end. Inspect the bracket very carefully for cracks, especially at the neck.

Note.—The inspection for flaws and defects of all steel components will be facilitated very considerably by use of the Magna-flux process.

(2) The Blade Bushing

This should be checked for wear on the flange and in the bore. Any roughness on the flange should be smoothed down and the bore must be measured in both diameters and referred to the dimensions of the spider arm in order to check the clearance at these points. If the clearance is greater than the specified amount, the blade or blades in question must be withdrawn from service and fitted with new bushings.

(3) The Blades

All blades are inspected daily for cracks or nicks as described in the section on "Maintenance." When controllable-pitch airscrews are used over loose aerodrome surfaces or in water spray, the leading edges of the blades may become pitted and ragged.

In time this may seriously affect the efficiency of the airscrew by destroying the true airfoil section, and if left too long, fatigue cracks may occur at these points and failure may result.

If nicks and erosions are eliminated in the early stages, the blades will retain their efficiency, and the slight effect on balance will not be noticeable in operation. Sharp dents, nicks, and gashes should therefore be attended to at once, and may be removed locally without the necessity for reworking the entire blade surface.

For removing a nick or dent, a curved riffler file or scraper is recommended, and fine emery cloth and crocus powder should be used for polishing. When all marks left by the file or emery cloth have been removed, the restored portion of the blade may with advantage be lightly burnished and smeared with lanoline. In smoothing out defects the main essential is to convert sharp-cornered indentations into smooth, rounded depressions, and the amount of metal that it is permissible to remove in

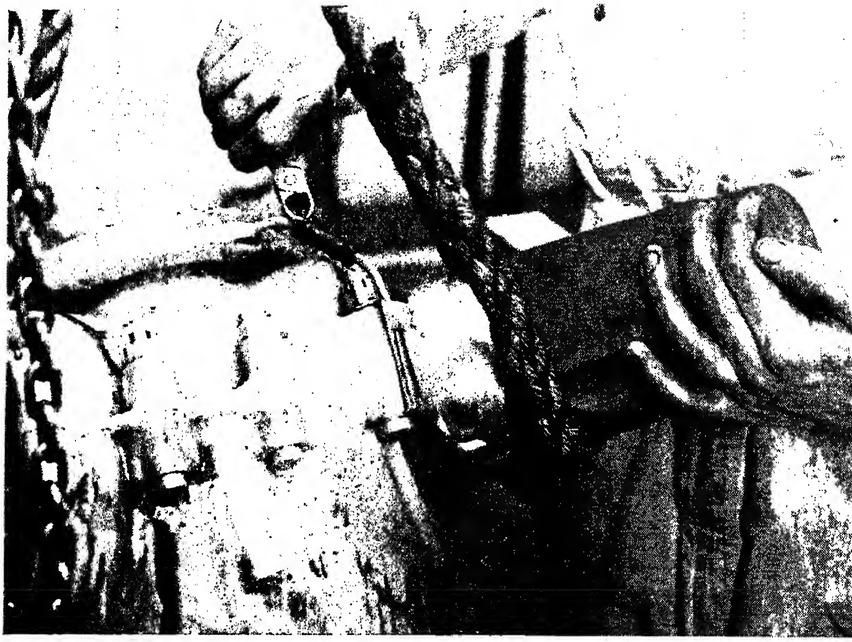


Fig. 9.—Disconnecting de-icing pipes

Fig. 10.—Taking off slinger ring

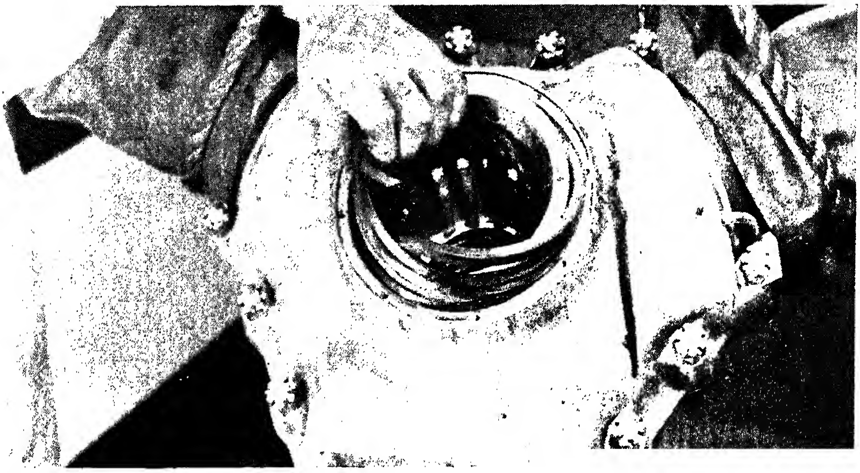


Fig. 11.—CHEVRON PACKINGS HAVE TO BE REMOVED

this way is shown in the table and illustration at the end of this section. Airscrew blades on which the defects are too numerous or are beyond the given limits must be withdrawn from service and returned to the manufacturers for repair.

The foregoing relates to superficial damage which is clearly the result of erosion, impact, or damage accidentally sustained in handling the airscrew. Should, however, the damage take the form of a faintly defined irregular crack, it may imply a fissure in the material of some depth, and calls for further remedial action to that indicated above.

Should such a case occur, the crack will be removed by scraping or filing in the usual way, and at intervals the depression should be polished up in order to disclose if the crack has been removed to its full depth. When this stage has been reached, it is recommended that the depression be etched locally to make quite sure that no trace of the fissure is left and remains imperceptible by reason of being burred over in the polishing process.

The etching is carried out with a solution consisting of 5 parts of 10 per cent. aqueous sulphuric-acid solution and 1 part concentrated hydrofluoric acid, which should be applied to the surface under test by constant swabbing, or if the position of the airscrew admits, by filling the depression with etching solution.

The etching process should not be continued beyond one minute.

The surface must then be washed with cold water and swabbed with a 50 per cent. aqueous nitric-acid solution until the surface is free from the deposit formed by the etchant.

This treatment leaves a surface in which the smallest crack will show up well under a magnifying glass.

After this treatment the blade should be thoroughly washed and the

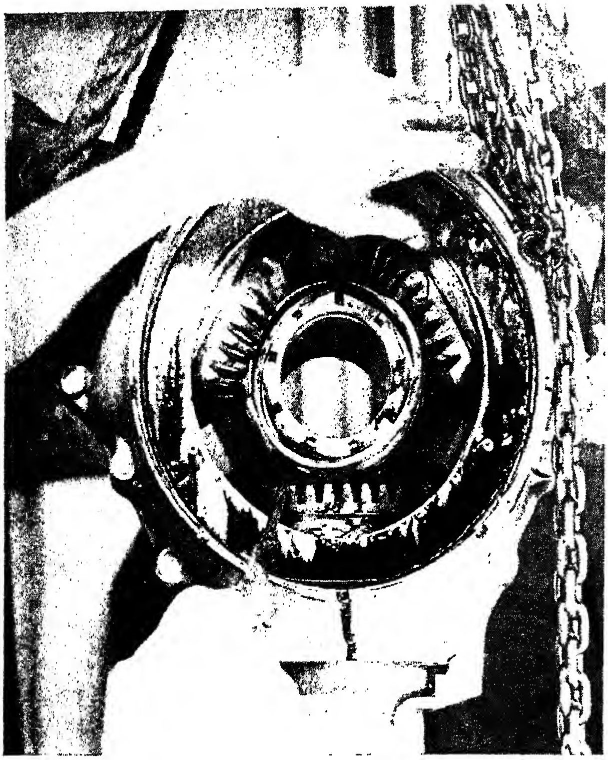


Fig. 12.—TAKING OUT AIRSCREW SNAP RING

depression again smoothed out before being polished finally and burnished.

Tolerances of Similarity

It will often occur that blades returned to the manufacturers for repair will require to be reshaped along the edges or at the tip, and where the damage is extensive, the blade will be restored to a new drawing number, and will then only be suitable as spare on a different type of airscrew—usually of less diameter.

Where, however, the damage is only slight, the blades will be restored at, as nearly as possible, the original dimensions, in order that they may be held as spare and used in the type airscrew for which they were designed originally.

Such blades will be adjusted for balance as described later, but in order that they may be also in aerodynamic balance, it is necessary to limit the amounts by which they vary from the other blades in their similar dimensions.

These tolerances are given at the end of this section.

Wherever possible, spare blades within these tolerances should be fitted, but if these are not available, then the larger blades in the airscrew must be refinished to the size of the smallest within the similarity tolerances.

(4) The Spider

The spider must be carefully examined for cracks, and all bearing surfaces must be checked for chafing or pick-up and for dimensions. Any material plucked from the blade bushing remaining on the spider arms should be removed by stoning, after which the bearing surfaces should be repolished.

Fig. 13.—THE AIRSCREW RETAINING NUT IS REMOVED WITH FRONT CONE (SPLIT)

Pick-up of a similar nature may occur in the front cone seating of spiders with parallel splines. This is usually an indication that the airscrew has not been sufficiently tight on the engine shaft, and it will generally take the form of small lumps or weals on the front cone or airscrew shaft, with corresponding depressions in the surfaces of the spider-cone seatings. Where less than 10 per cent. of the bearing area is affected, this condition can be remedied by smoothing the cone seatings, and stoning off the deposits on the male components, which should then be " blued in." In excess of this the spider should be returned to the manufacturers for rectification.

Local Corrosion on the Spider

Any local corrosion found upon the spider should be stoned out and smoothed over.

In carrying out such rectification to the rear cone seat of parallel splined spiders, it may be necessary to resort to lapping in order to restore a 90 per cent. contact on the airscrew shaft. In such cases, since the cone seating is true to the side surfaces, but not necessarily true to the tops or bottoms of the spline, it is desirable that a lapping jig should be used to preserve this alignment. Such a tool can be provided for use with parallel splined spiders, or this rectification can be carried out at the manufacturers' works.

After correction of the cones, they should be assembled in position on the spider, and the whole unit, mounted on a splined sleeve and balancing mandrel, should be checked for concentricity on the outside ground diameter on the spider.

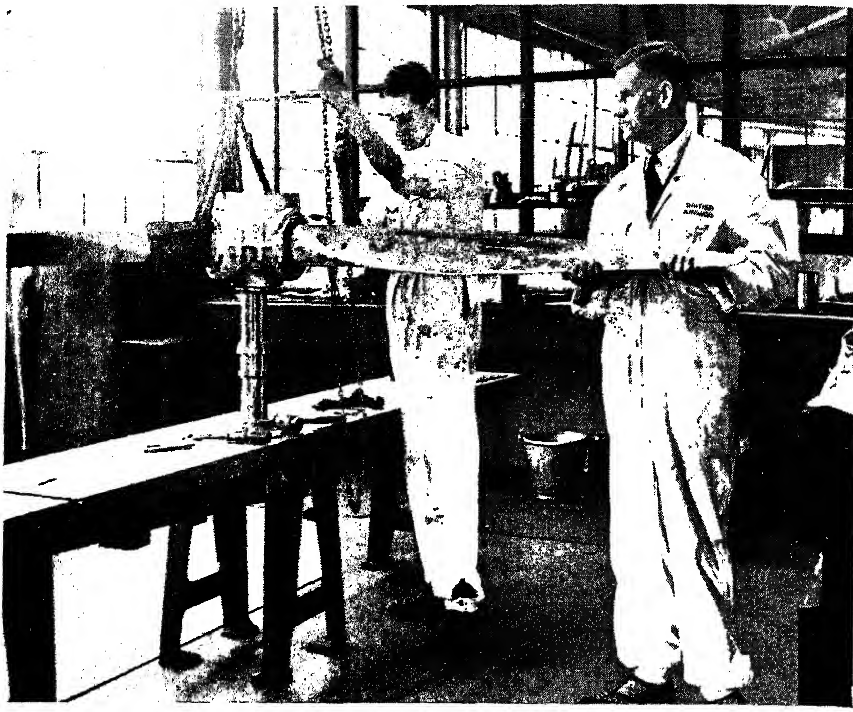


Fig. 14.—Lowering airscrew on to assembly table

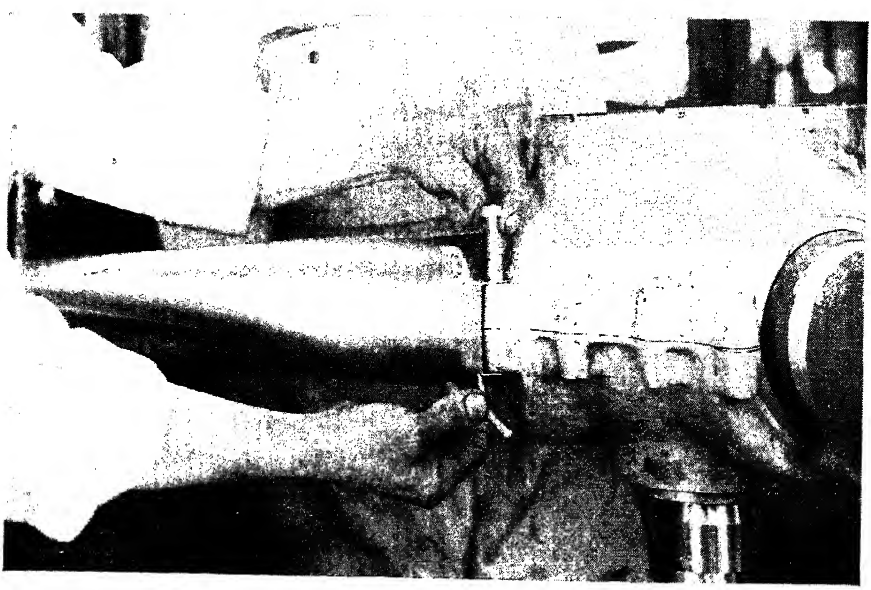


Fig. 15.—Barrel bolts are now removed (split pin)
The above illustration also shows de-icing bracket and nozzle assembly.

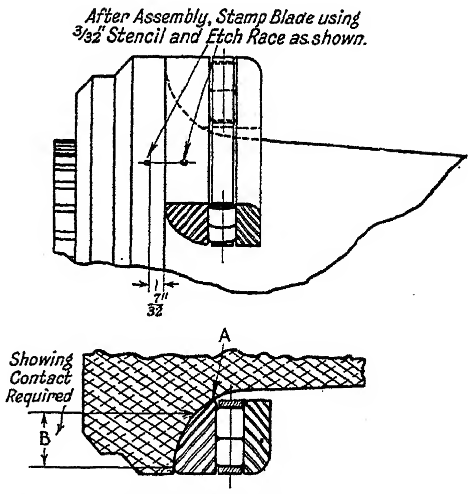


Fig. 16.—Fitting of thrust-race bearing

Occasionally it is found on taper spline shafts that a small wrinkle is thrown up on the airscrew shaft on the maximum diameter at which the spider makes contact. In all cases this must be stoned off in order that it shall not prevent the airscrew from going full-tight into position when re-installed.

The splines in the airscrew spider will not normally require attention, as it is more convenient to remove any hard bearing spots by stoning the splines of the engine shaft. They should, none the less, be inspected for damage or chafing due to initial slackness, and any roughness should be removed by slip-stone.

(5) Blade-thrust Bearing

The thrust rings and roller-bearing cage should be inspected for wear and cracks, and the inner ring should be blued to the blade root to ensure that the fit specified is obtained. Hard bearing spots or areas must be relieved by careful hand scraping and the use of fine emery paper.

In observing the markings given by the blueing operation, the fit must be good at point B, but clear of the shank at point A. Contact on surface B should be approximately two-thirds of the whole bearing surface, and the clearance at A should not exceed ·003 in. Blade and bearing race are marked as shown in the illustration to ensure correct assembly.

Service experience indicates that some wear of the rollers and thrust-race faces may be found after extended operation periods, the rollers becoming flatted or corroded and the races becoming indented at the positions the rollers take up in coarse pitch. This type of wear is not serious, and will not cause any difficulty until it becomes excessive, when sluggish pitch-change may result. The rollers should then be changed, and when necessary blades may be returned to the manufacturers to have the thrust races refaced.

(6) Index Pins

The four index pins which hold the counterweight bracket to the blade bushing must be a light tap fit. Oversize pins should be fitted as required to maintain this fit.

(7) Counterweight Bearing

The counterweight bearing must be inspected for chipping or corrosion of balls and brinelling of the tracks in the ball and cap races. Any con-

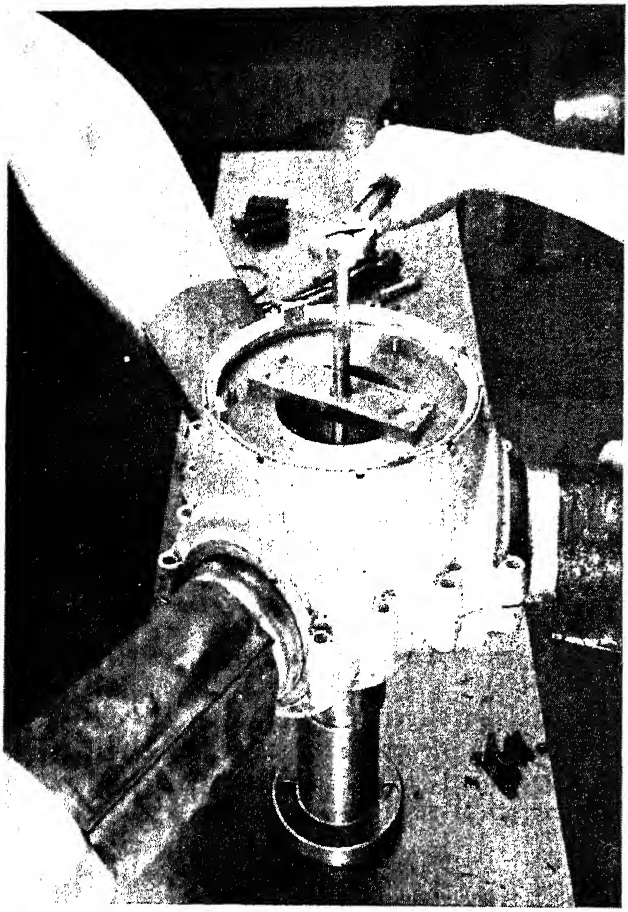


Fig. 17.—USING SPECIAL TOOL TO SPLIT BARREL, WHICH EASES THE BLADE-PACKING NUTS, ENABLING THEM TO BE UNSCREWED, AS SHOWN IN FIG. 18.

siderable amount of wear on either of these components which might interfere with the working of the airscrew should be a reason for replacement. The counterweight spacer should not normally be subject to any serious degree of wear, and will usually only be replaced when damaged by accident.

(8) Counterweight Bearing Shaft

It is convenient to consider the counterweight bearing shaft in conjunction with the counterweight races for purposes of inspection, as the two are bound up together with the thrust race located in the cylinder flange in questions of adjustments and working clearance.

The counterweight bearing shaft is screwed hard down upon a stop pin which is permanently located at the bottom of the hole in the cylinder flange, into which the bearing shaft is fitted. This bearing-shaft stop pin is faced down on new assemblies until, when the bearing shaft, which is produced within close limits on overall length, is screwed hard down upon it, the resulting clearance between the thrust washer and the back of the counterweight bracket will be of the order from ·002 in. to ·003 in.

In this assembly it will be observed the wear and tear is confined to two ballraces and an Oilite thrust washer, none of which is heavily loaded, and all of which are completely interchangeable with spare parts. It should rarely be necessary, therefore, to change the bearing shaft in

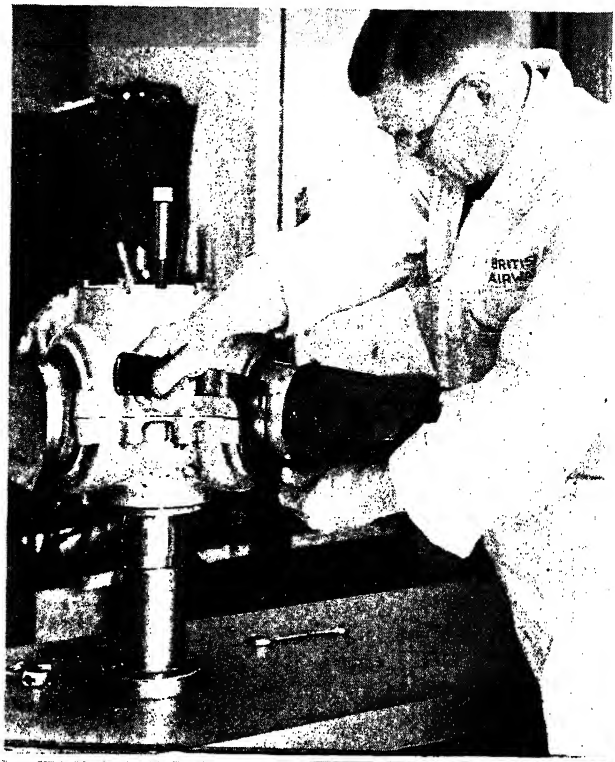


Fig. 18.—Unscrewing the blade packing nuts

order to adjust clearances, and usually it will be conditioned from the dimensional point of view only.

Renewing Counterweight Bearing Shaft

Where for any reason it is required to renew a counterweight bearing shaft, the replacement should first be tried in position, and any adjustment required to procure new clearances should be effected at the screwed end, which may be faced back as necessary. Facing back should, wherever possible, be done in a suitable grinding machine.

The shafts are deposited with tin as an anti-corrosive treatment, and should not therefore be scoured or polished with emery paper.

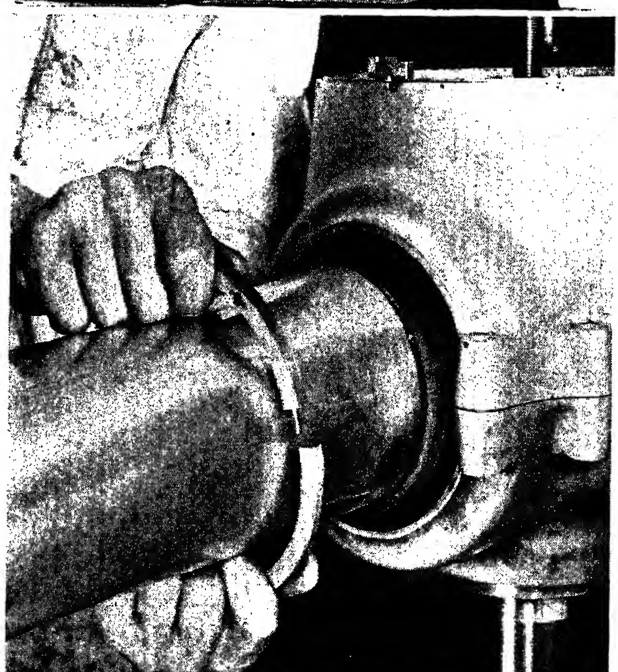


Fig. 19.—Method of splitting the blade-packing nut

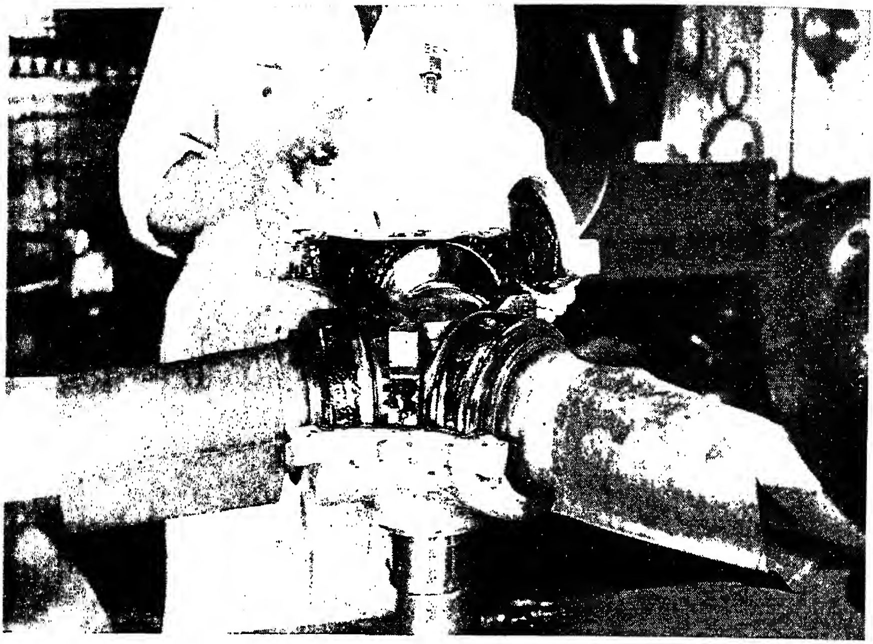


Fig. 20.—Taking off the front half of the barrel

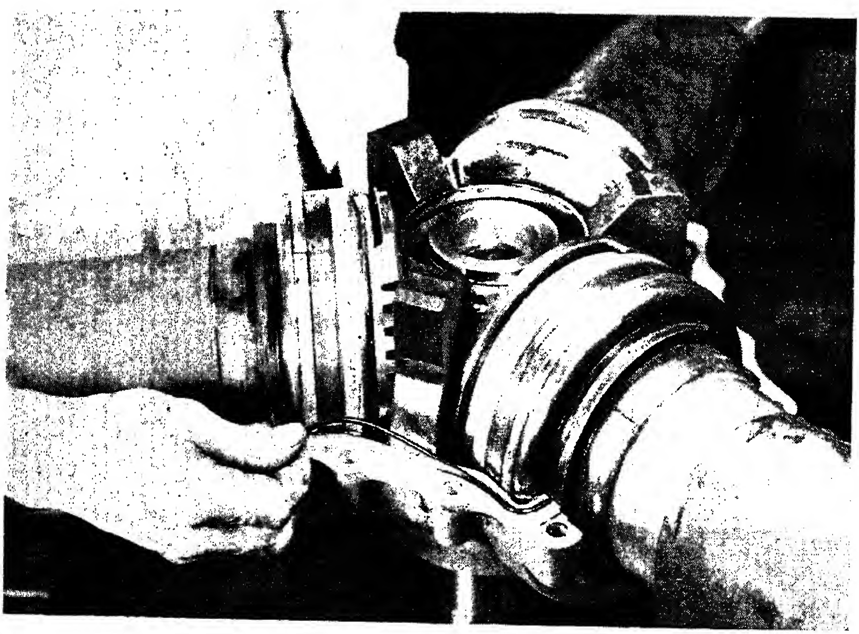


Fig. 21.—Taking out barrel half oil seals

There are three of these.

(9) Cylinder Assembly

Cylinder wear or roughness in the bore at points of contact with the piston cup leathers should be smoothed out with fine emery cloth and polished with crocus powder, using a circular motion so as not to destroy the shape of the cylinder bore. The slight variations in diameter or in contour resulting from this treatment will not affect the efficiency of the oil seal, as the piston leathers are sufficiently flexible to follow small irregularities.

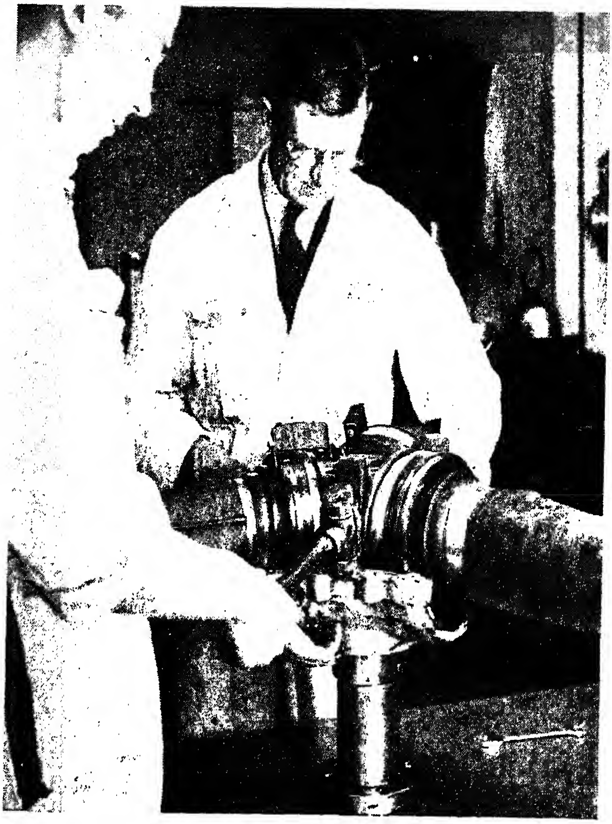


Fig. 22.—Lowering the rear half of barrel

The cylinder should also be inspected for cracks, and the bore diameters of the bearing-shaft bushes should be gauged for wear. These latter are an interference fit in the cylinder flange, and where it is required to exchange them, it is necessary to use an extractor to remove them. After pressing in the replacement bushes they require to be reamed in position, in order to size them for the counterweight bearing shafts. Where this repair is required, it is recommended that the cylinder be returned to the makers for attention.

Additionally the cylinder is provided with a cast-iron liner in the bore; and a micarta liner in the small-diameter bore, where it makes contact with the piston. Both of these are replaceable when worn beyond maximum limits.

(10) Piston Assembly and Piston Cup Leathers

The piston should be inspected for condition of threads, and any chafing marks or scoring should be stoned over and made smooth.

The piston head, springs, piston-head securing screws, draw bolt, and draw-bolt bucket should be inspected for damage or defect—they

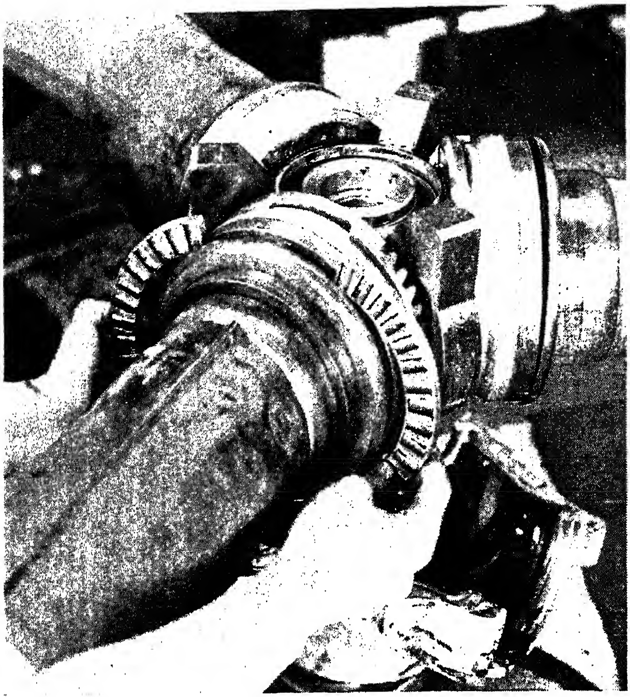


Fig. 23.—TAKING OUT BLADE THRUST BEARING RETAINER

will not normally be subject to much wear. Magna-Flux will facilitate these inspections.

Cup leathers must be of even texture and not too soft.

If they are dragged in the securing screw holes, split or cut at any point, they should be discarded.

(11) Barrel and Barrel-support Blocks

The barrel should be inspected—preferably by Magna-Flux—for cracks or defects and also for marking by the counterweight brackets in the front aperture.

Any such marking should be blended out to afford increased clearance to the bracket.

The barrel is a most important component, and it is recommended, in order that there shall be no precaution neglected, that it be Magna-Flux tested as often as opportunity permits, but not exceeding, in any case, an interval of 500 hours.

The coating of cadmium with which the barrel is plated does not preclude this test, and it is not necessary, therefore, to deplate these components, unless by reason of corrosion or patchiness they require replating.

The barrel-support blocks are dowelled to the spider by means of a dowel tube, which should be inspected for wear and looseness and discarded if these defects are apparent.

Wear of the micarta material is expected to proceed uniformly and may eventually produce such looseness in the assembly that abrading of the contact faces may occur.

As soon, therefore, as any looseness is apparent in the assembled condition, or any abrasion (as distinct from chafing, which should be smoothed down) is observed, the blocks should be exchanged.

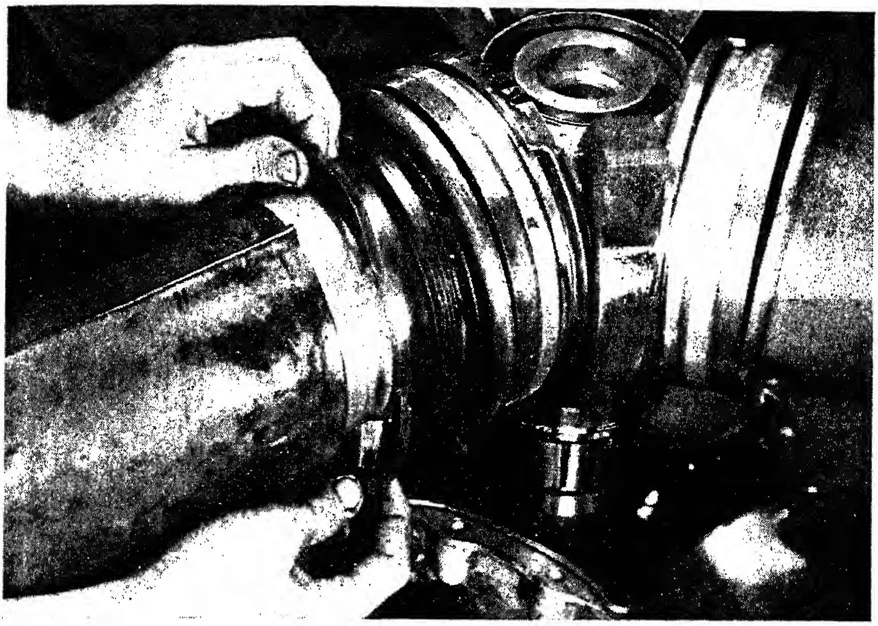


Fig. 24.—REMOVING SPLIT HEADER AND FOLLOWER RING
The three middle rings are of synthetic rubber (oil resisting).

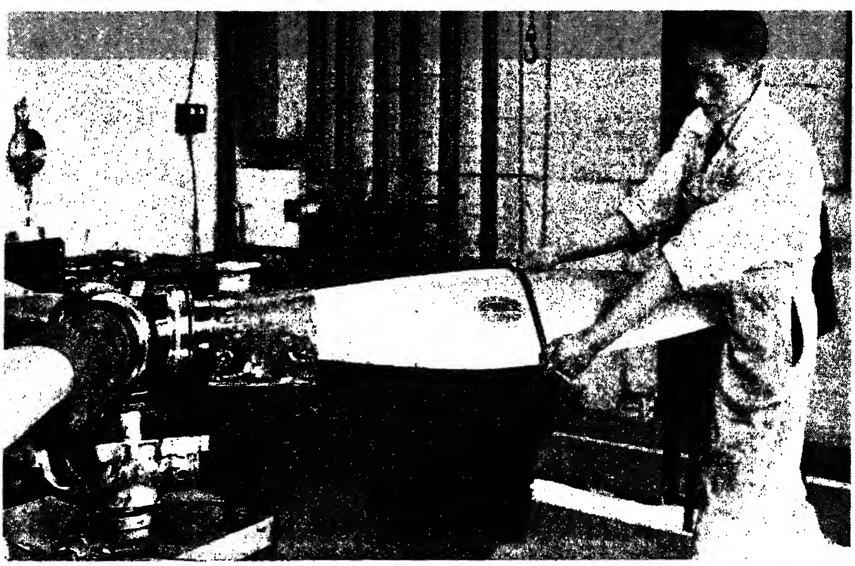


Fig. 25.—THE MIDDLE RINGS ARE VEE-SHAPED AND ARE STRETCHED OVER THE BLADE AS SHOWN

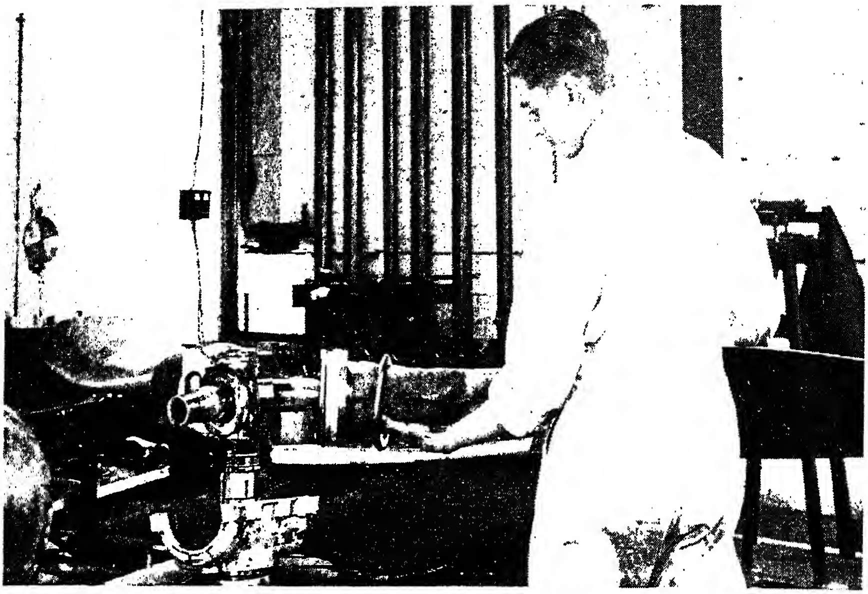


Fig. 26.—Removing blades from spider—straight pull

(12) Packing Plates and Shim Packs

The packing plate is manufactured in "Oilite" bronze, a material which is self-lubricating, and which should not therefore be washed in petrol or paraffin, but merely wiped clean.

No attempt must be made to reduce the thickness of these plates, but in the event of roughness appearing on the surface, it may be removed with a sharp flat scraper. After inspection, packing plates (and "Oilite" thrust washers) should be soaked in hot engine oil for twenty-four hours, to renew the self-lubricating properties.

The laminæ of shim packs are liable to buckle or tear if separated from the main body, and any in which such separation has begun should be discarded.

Similarly, it is not permissible to make up the required thickness of shim packs by assembling loose laminæ.

(13) Cylinder-head, Snap Ring, Front Cone, Joint Rings, etc.

The cylinder head and draw-bolt nut should be inspected for damage, particularly to the hexagon, as occasionally attempts are made to unscrew these components without first removing the lock rings.

Snap ring and front cone are liable to damage from distortion (snap ring), chafing, scoring, and plucking.

These items must be stoned over to remove any roughness or irregularity, after which the front cone should be "blued" into the spider to show a 90 per cent. seating.

Joint rings and washers are conditioned to the usual standards and replaced as required.

Fig. 27.—SHOWING SLIGHT PICKUP FROM BLADE BUSHING

This has to be stoned. To ensure that each shim is reassembled with its respective shim plate, both the shims and shim plates are numbered 1–2–3 for register in reassembly.

REASSEMBLY OF AIRSCREW AFTER OVERHAUL

After all rectification work has been carried out, the airscrew should be reassembled, following the sequence of operations given below:

(1) Clean splined sleeve.

(2) Place rear half of barrel over splined sleeve.

(3) Place spider in position on the splines of the sleeve. In the case of parallel splined airscrews, the rear cone may be a detachable engine fitting, and in such cases must be placed on the mandrel before the spider is mounted.

(4) Fit greasing nipples into spider.

(5) Fit barrel support blocks in numbered positions with nipple apertures towards the rear. Ensure that the numbers on the barrel apertures coincide with the numbers stamped on the spider arms.

(6) Assemble laminated shims and packing plates on spider.

(7) If new blade bushings have been fitted, care must be taken to see that they have been inserted in their correct position, as indicated by suitable markings made prior to the extraction of the worn bushings. The blade bushing screws must be locked by swaging the metal of the bushing into the screwdriver slot, using a spherical-ended punch.

(8) Assemble counterweight brackets on blade bushings, making certain that the index pins are in the correct position for the required basic pitch setting, which is stamped on the lead plug provided for that purpose in the counterweight.

(9) Fit oversize index pins as required.

(10) Fit grease-retaining rings on spider arms.

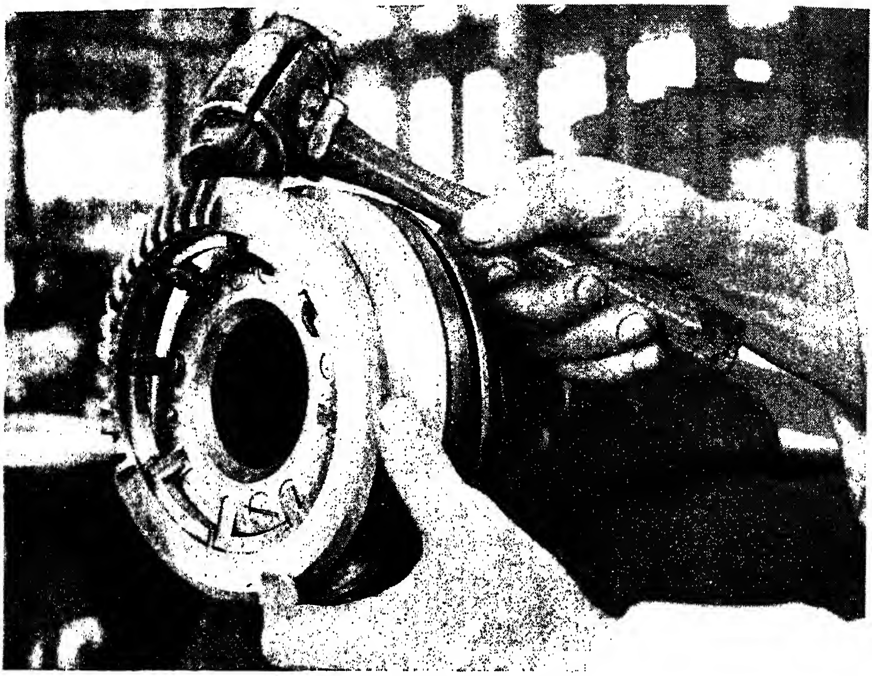


Fig. 28.—Removing barrel support and barrel shim

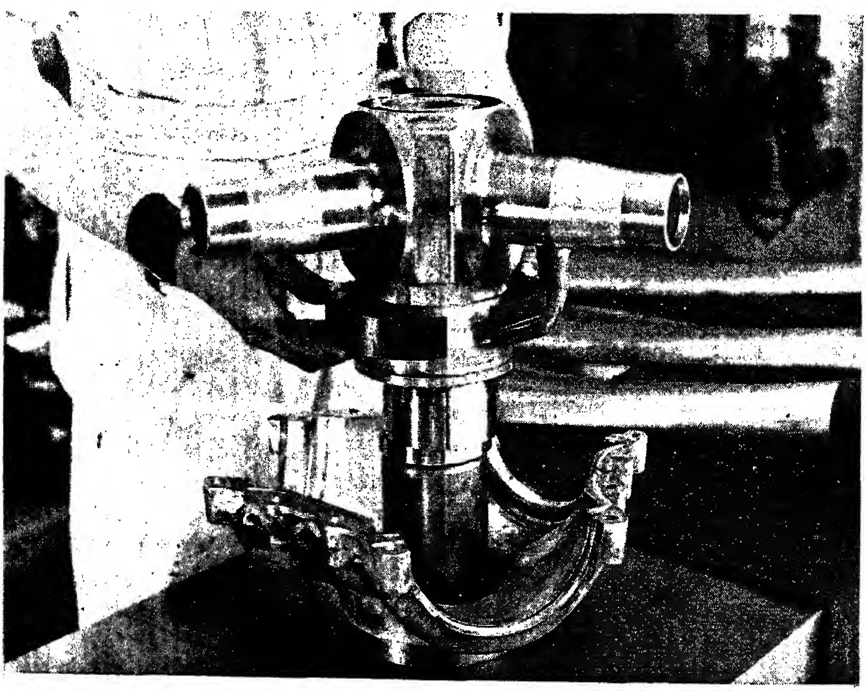


Fig. 29.—Removing barrel chafing ring

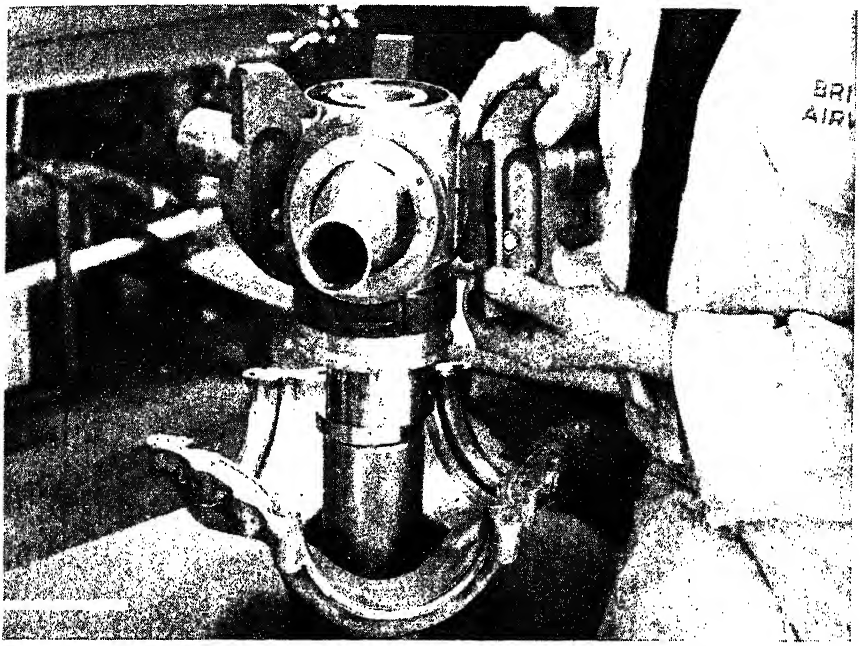


Fig. 30.—Blade gear segment, showing spring packs

(11) Assemble blades on spider arms.

(12) Fit split-bearing cages to the thrust-bearing races on the blade shanks and hold in position with spring clips to prevent cages dropping. Check position markings, taking care that the bearing cages, which carry two rows of rollers, are mounted the correct way round, i.e. with joint vertical and the positioning marks " 0 " on the inner thrust race and blade shoulder mating.

(13) Before lifting the lower half of the barrel, insert slips of cardboard or other suitable material between the inner diameter of the thrust and the blade shanks to prevent the latter from being marked by the thrust races.

(14) Lift the lower half of the barrel to its proper position and drive home with rubber mallets. Tap down split roller cages until they register in the bottom half of the barrel. The spring clips holding the thrust-bearing assembly may now be removed.

(15) Mount the top half of the barrel in its correct position with all numbers matching up. Particular care must be taken, when mounting the top half of the barrel, not to damage the necks of the counterweight brackets. It will be found that as the top half of the barrel settles into place, the blades will have to be turned in order to prevent this occurring. Do not attempt to turn the blades by hammering the counterweight brackets, as they and the blade bushings are not designed to support such treatment and may be damaged thereby.

Fig. 31 (*left*).—SHOWING THE BLADE BUSHING AND SHIM PLATE DRIVE PINS

Bolt the two halves of the barrel together with appropriately numbered bolts and nuts, and tighten up.

(16) The torque loading of the blades should be checked at this stage by turning the blades within the hub.

It is possible to move a 5,000-size blade by hand, if it is within the permissible torque loading, but it is to be preferred that this check may be made using a wooden lever, clamped to the blade at about the 20-in. station, on which are hung weights, or a pull may be measured through a spring balance—sufficient to move the blade, which should turn smoothly.

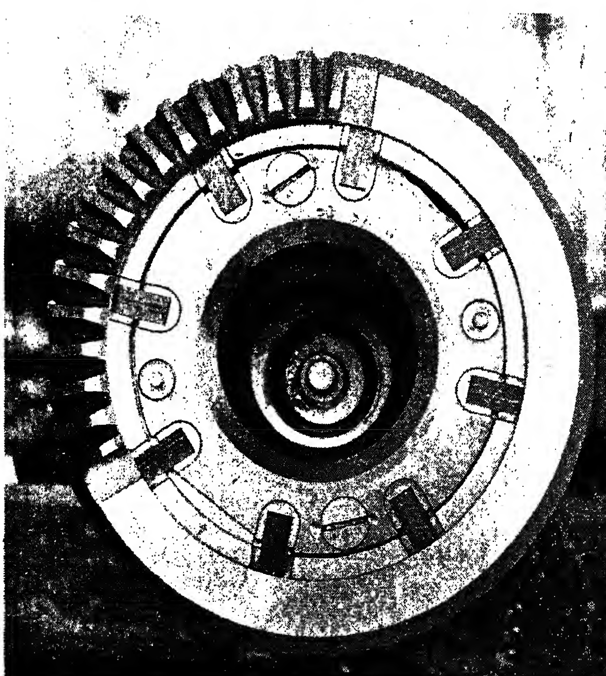


Fig. 32 (*right*).—BLADE SPRING PACK RETAINER

Note clearance for gear springload.

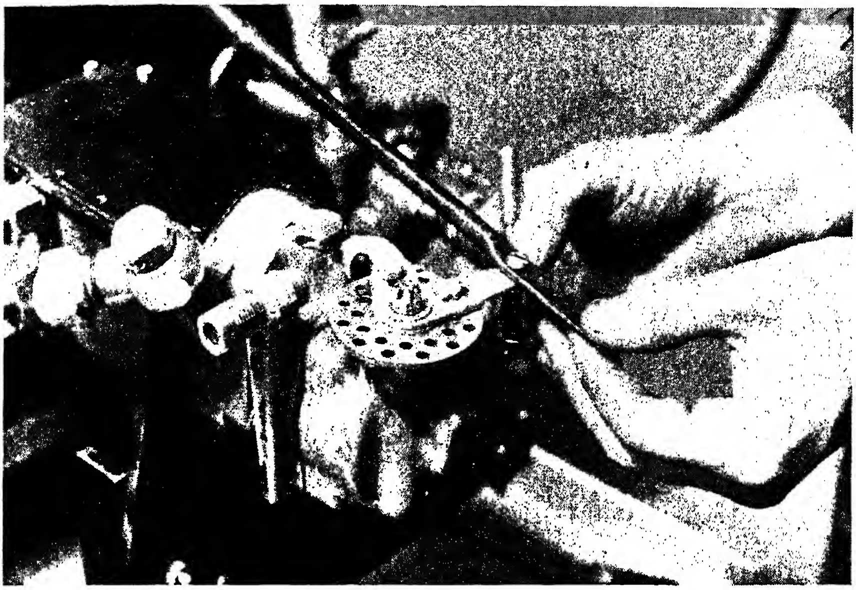


Fig. 33.—TESTING A CONSTANT-SPEED CONTROL UNIT

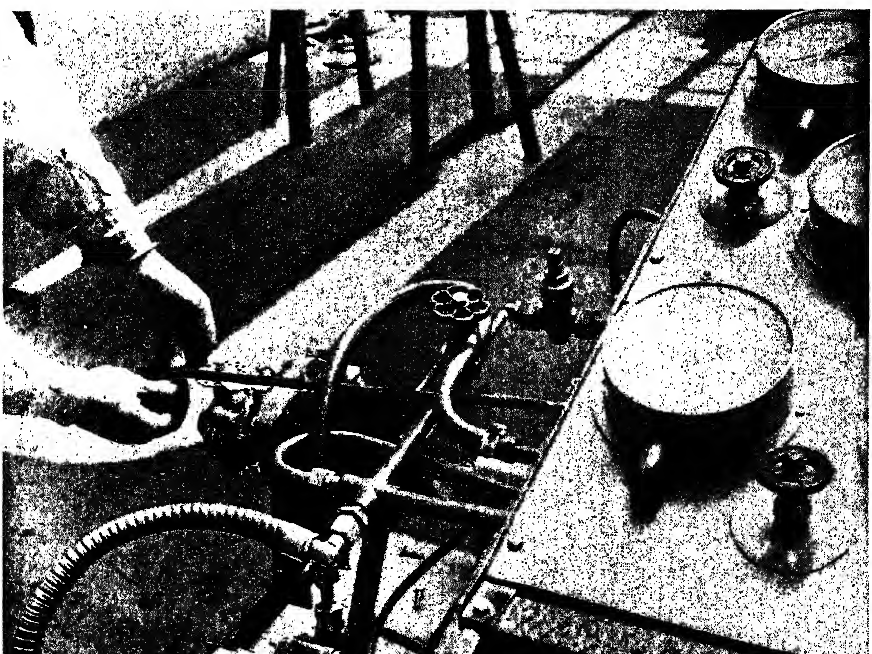


Fig. 34.—ADJUSTING CONSTANT-SPEED UNIT ON TEST

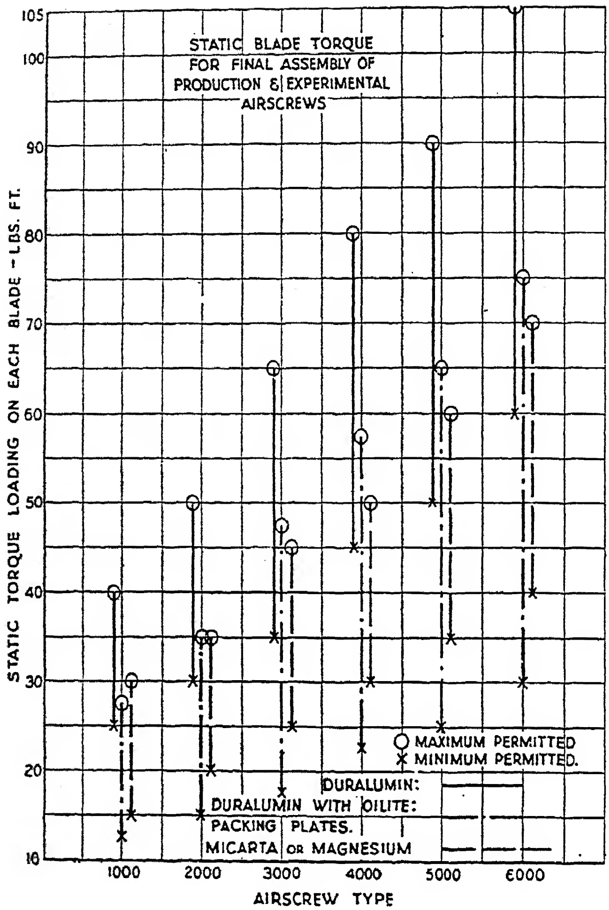


Fig. 35.—Torque loadings

The object in preloading the blades in this manner is to reduce the effect of the centrifugal pull of these components when the airscrew is rotating.

In the larger sizes this pull is as much as thirty tons per blade, and it has the effect of stretching the barrel to such an extent as would result in undesirable slackness of the blades under working conditions were they fitted to move freely in the first instance.

On all new airscrews, therefore, the shim packs behind the packing plate are proportioned to produce the torque loadings specified in Fig. 35, but it may be found that this initial loading has first reduced as the components settle down together, and then, after considerable running time, has increased to a much higher value. This tendency of the torque loading to increase occurs by reason that the bushing is shrunk into a tapered bore, and under alternating stresses and vibration it inclines to squeeze out as would an ice wedge from between the fingers. It is secured by two screws through the flange across the diameter, however, and so cannot move bodily; but at right angles to this line it is not constrained, and by distortion the bushing may move slightly with reference to the blade, so producing a slight buckle in the flange, which then stands away from the face of the blade at two points opposite each other.

This condition can be detected by trying to insert feelers behind the blade bushing flange, but it will be apparent that the bush can only work back whilst the airscrew is rotating, and only so far as to take up

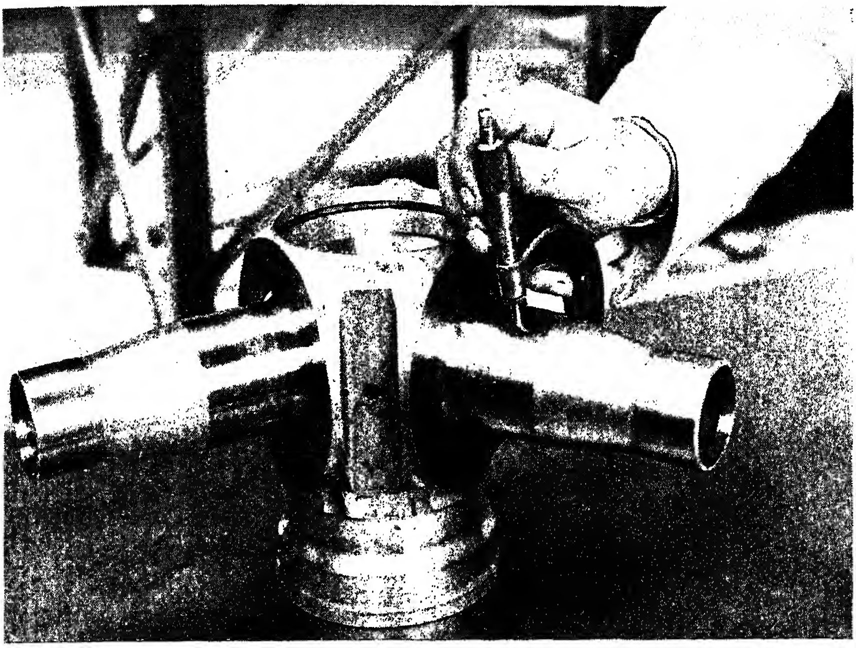


Fig. 36.—Measuring the diameter of the spider arms

the additional clearance given to the thrust assembly by the stretch in the barrel; hence the process is self-regulating and need occasion no concern.

Providing the blades move smoothly, therefore, and are within a few pounds feet of each other, no attempt should be made to reduce

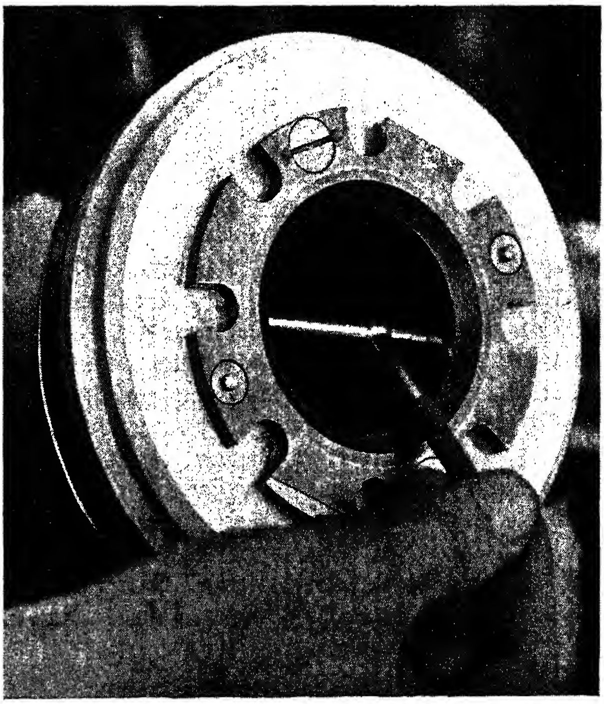


Fig. 37.—Checking inside diameter of blade bushing

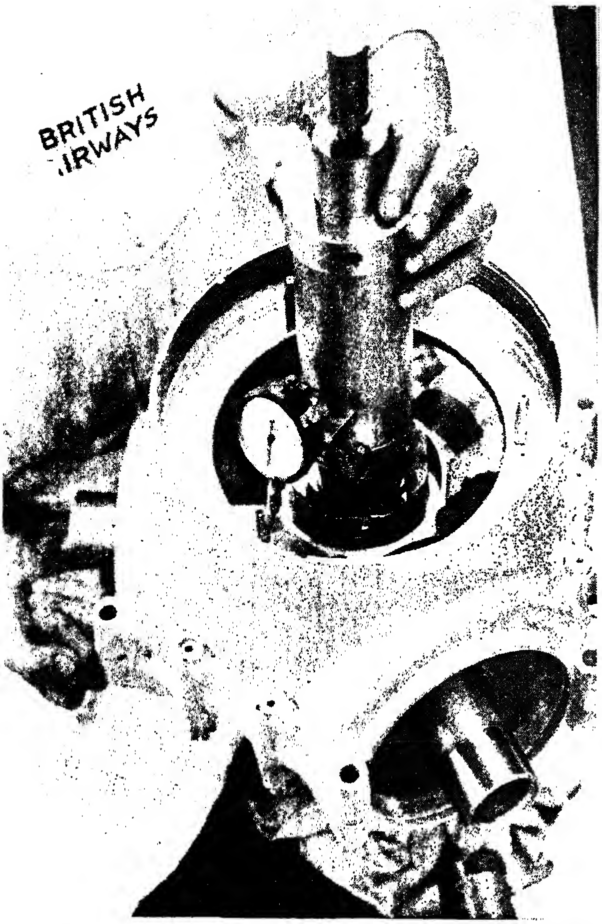


Fig. 38.—CHECKING BARREL AND SPIDER ALIGNMENT

the torque loading on repair airscrews to the original value, unless a complete set of new blades has been fitted.

Where, however, the torque loading is below this minimum value, or differs widely from blade to blade, adjustment should be made by fitting shim packs of increased thickness in the first case and as may be required in the second.

(17) Assemble the piston and the cylinder with the inner and outer cup leathers in position, but leaving off the piston head, spring-draw bolt, bucket, springs, etc. This procedure is necessitated by reason that the balancing mandrel will not pass through the piston head, but as all these components are concentric with the axis of rotation and the leathers will usually be stiff enough to centre the cylinder on the piston, balance is not affected by leaving out these components, nor when subsequently they are replaced.

(18) Assemble the piston lock ring, spider snap ring, front cone, and packing washer on the piston, and screw the latter on to the splined sleeve, taking care to get the cylinder bosses in the numbered positions corresponding with adjacent counterweight brackets. Tighten down firmly with the piston box spanner.

(19) Assemble the counterweight thrust races and thrust washers in position, and turn the cylinder until these make close contact with the counterweight brackets.

(20) Insert counterweight bearings in the counterweight brackets.

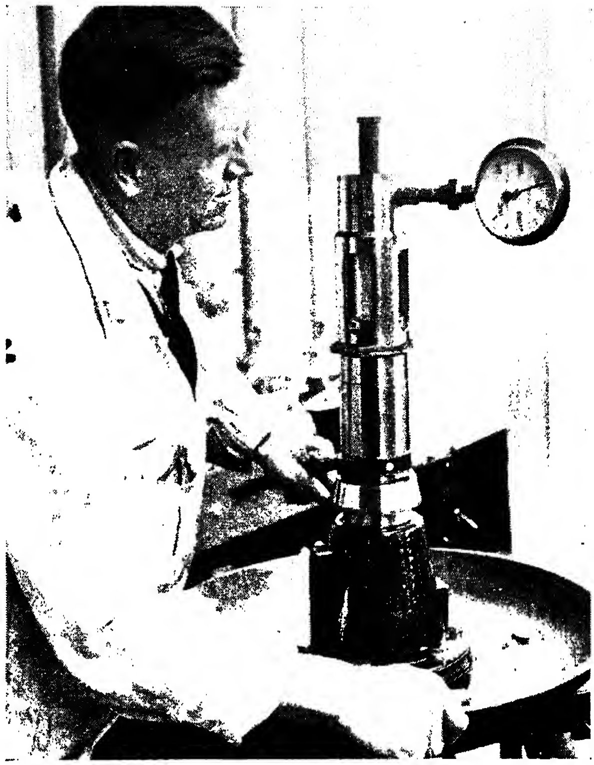


Fig. 39.—Testing distributor valve

Make sure that the round cap race is fitted in proper relation to the curved tracks in the bearing races. An arc is engraved on the back of the cap race indicating the curvature of the ball tracks on the underside to provide a visual check that the assembly is correctly made.

(21) Screw the counterweight bearing shaft into the correspondingly numbered position in the cylinder flange and lock with securing pin.

(22) Assemble counterweights on their respective counterweight brackets, and fit cheese-head screws and washers.

(23) Insert the counterweight adjusting screws and nuts into the slots in the counterweights, with the nuts set to the required pitch angles.

(24) Check the blade angles at the 42-in. station. This check may be carried out, using a spirit-level protractor, but it is preferable that it should be made with the airscrew mounted on its splined sleeve and mandrel upon a true surface table, using a vernier protractor.

In either case the cylinder is extended to the full length of its travel in both directions by means of the pitch adjusting tool, or a scrap cylinder head provided with a hand bar, and the blade angles are measured in each position.

With the head of each counterweight bearing shaft touching in turn the stop nuts which limit its travel, the difference between the angles of any two blades of the same airscrew should not exceed $\cdot 2°$ in either high or low pitch position, and all blades should be within $\pm \cdot 20°$ of the specified angles in both positions. A tolerance of $\cdot 3°$ difference between the angles indicated by the counterweight scale readings and those determined by the protractor is permitted in new airscrews to cover the cumulation of manufacturing tolerances. It should, however, be borne in

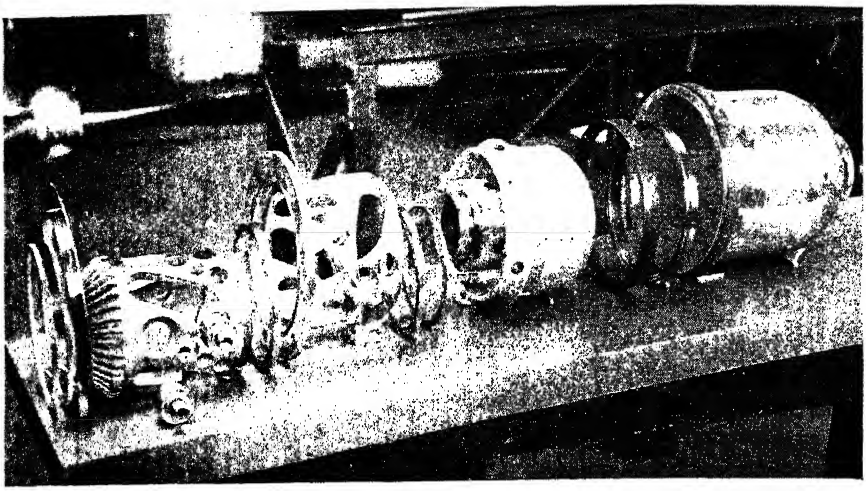


Fig. 40.—Dome assembly extended

mind that these last markings are merely an index whose use, primarily, is to afford assistance in making the preliminary rough settings. They should not be relied upon in any circumstances as indicating the actual angle of the blades.

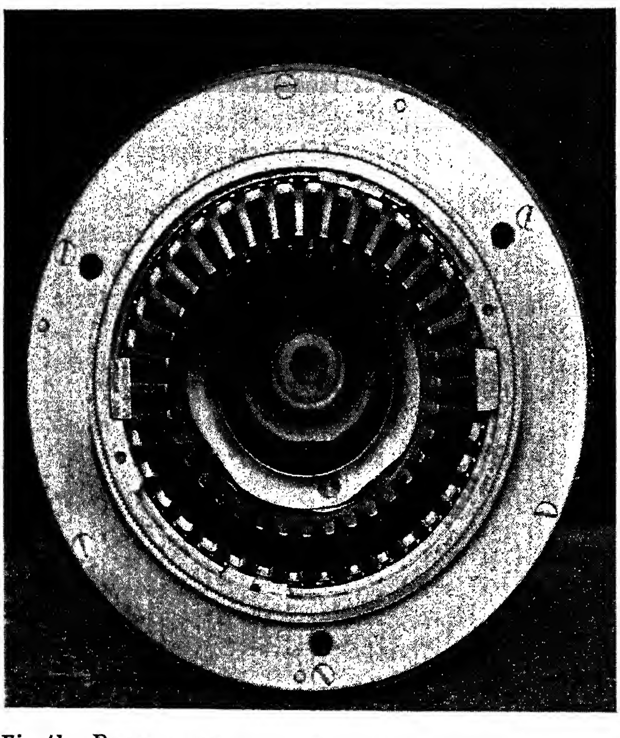


Fig. 41.—Dome assembly with positive high and low pitch stops

(25) Screw on the counterweight caps, insert the locking pin, and secure with split pins. These caps are screwed on in the first instance with just sufficient force to take up slackness.

Subsequently, care must be taken to see that they are not over-tightened on the counterweights. They should be screwed up slowly and carefully with

Fig. 42.—Checking the blade torque

the locking pins held lightly in position, so that immediately the holes register the pins will drop into place.

Tight caps may be eased by rubbing the joint faces on a sheet of emery paper laid flat upon a surface table, until they can be put up comfortably to within half a hole of alignment, in the securing pin holes, by hand.

Caps which already are too slack may be treated in similar manner until the holes are two diameters out of alignment when screwed up with the counterweight cap spanner. In this position a new hole may be drilled in the counterweight cap to pair with that in the bracket.

The airscrew is now ready for dry balance. The remainder of the assembly schedule follows at the end of the section on "Balancing."

BALANCING THE AIRSCREW

The balancing of any airscrew is of vital importance, and with controllable-pitch airscrews it must be carried out with the greatest possible attention to detail, because, unlike the fixed-pitch airscrew, many of the components are to some extent disposable around the axis of rotation, and may, therefore, affect balance.

Every de Havilland controllable-pitch airscrew leaves the factory in balance, and each component part has been balanced to a master before being put into stock.

These parts, therefore, are completely interchangeable as spares; but it will be appreciated, for instance, that if the thickness of both the blade root and the blade bushing flange of a replacement blade are

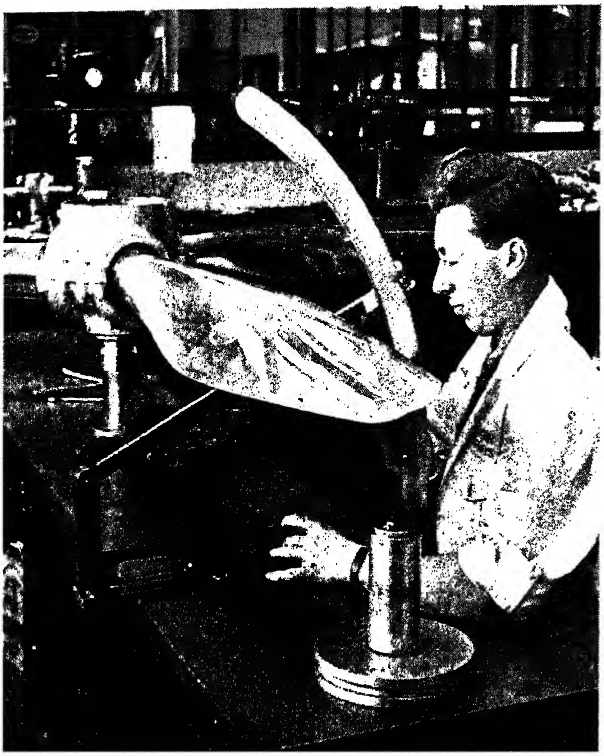


Fig. 43.—Checking the blade angles

on the low limit, it will be necessary to introduce a thicker shim pack to obtain satisfactory torque loading.

The effect of this adjustment is to remove the centre of gravity of the blade farther from the axis of rotation, and notwithstanding that the blade is the same weight and balanced to the same counterpoise as the others, it will be " heavy " in the airscrew.

If such a blade replaces one whose dimensions were on the high limit, the effect will be more marked, whilst equally it will be apparent that, if the components are not matched up in the same position as when the airscrew was built, the balance is likely to be adversely affected.

Notwithstanding the interchangeability of parts, therefore, the airscrew should always be balanced after overhaul, and even if no parts have been replaced, the operation is well worth while as a check on correct assembly.

To balance the airscrew effectively, the following equipment is required :

(*a*) A rigid balancing stand, with short and very stiff adjustable knife

Preferably the stand should be of welded construction and cross-braced, as the weight of the larger-sized airscrews at either end of the knife edges is liable to distort a non-rigid stand and so introduce error. Wooden erections, cantilever mandrels, or knife edges supported upon single uprights are generally quite unsuitable.

Knife edges should be checked periodically by means of a spirit level.

A convenient means of applying this check is to use a wide rectangular plate, provided with three buttons on the underside, two of which stand

on one knife edge and one on the other. The upper side of the plate is accurately faced, and the buttons are ground off to a uniform thickness measured from the upper surface of the plate.

In use the plate is rested on the knife edges, which are carefully levelled up to both the longitudinal and transverse readings of the spirit level on the upper surface, when the plate is turned end for end and the check repeated.

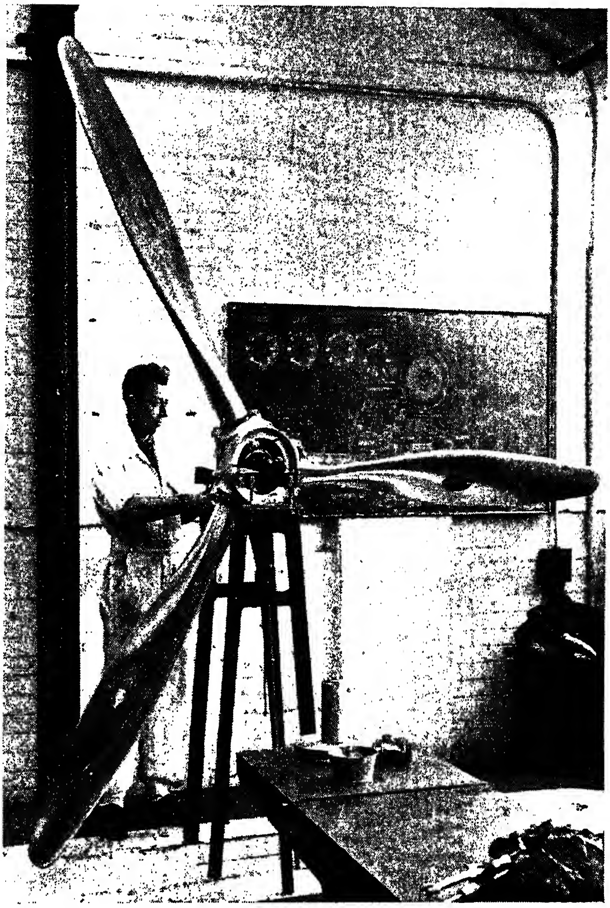


Fig. 44.—Balancing hub and blade assembly

(*b*) A balancing sleeve, suitably splined and provided with a rear cone for end location where necessary.

(*c*) A balancing mandrel which fits closely and accurately into the bore of the sleeve.

Before proceeding to mount the airscrew on the balancing stand, the splined sleeve and balancing mandrel should be checked on the balancing ways to ensure that the latter is not bent and that the two items themselves are truly in balance.

SEQUENCE OF OPERATIONS

(1) Reassemble splined sleeve in the airscrew as instructed in preceding paragraphs.

(2) Lift airscrew from assembling base, withdraw assembling mandrel, and fit the longer balancing mandrel through the bore of the sleeve.

(3) Using rope and tackle, mount the complete airscrew on the balancing ways.

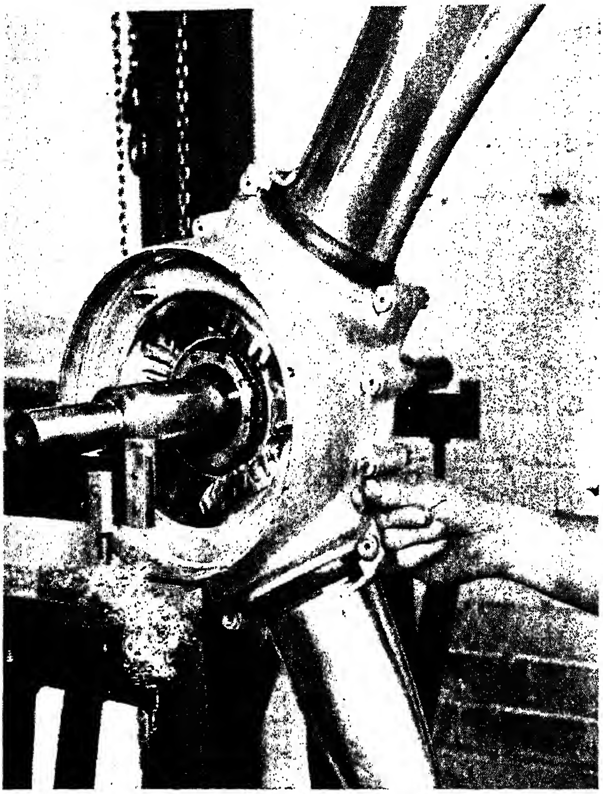


Fig. 45.—FILLING BARREL BOLTS WITH LEAD WOOL TO OBTAIN BALANCE OF HUB AND BLADE ASSEMBLY

(4) Check each blade in turn in the vertical and horizontal positions. If the airscrew is in balance, it will remain at rest in any position.

ADJUSTING BALANCE

Where the airscrew is not in perfect balance, but only a slight disposition to move is observed, a certain amount of compensation is provided for in the six hollow bolts which hold the halves of the barrel together.

If a blade falls away from the horizontal position, a correcting moment may be applied by ramming the bores of those bolts lying on the side remote from the heavy blade with the necessary amount of lead wool. In making this adjustment, the balance of the other blades must be considered, and in general the bolt farthest away from the vertical line passing through the axis of the airscrew should be selected, as less lead will be required in this position to produce the correcting moment, and the effect therefore on the balance of the other blades will be less pronounced.

In checking the vertical balance, loading the bores of these bolts is the only means of applying correction other than by the removal of material from the blade itself, and this means of correction should be regarded therefore as being available primarily for the requirements of vertical balance, which again is best effected by loading that bolt which is farthest removed to produce the necessary moment in the opposite direction to that in which the airscrew is disposed to turn.

The lead wool is retained in position by concave sealing caps, which are inserted into a recess in the bolt head and tapped flat into place.

Sometimes it will be found, after the replacement of a major com-

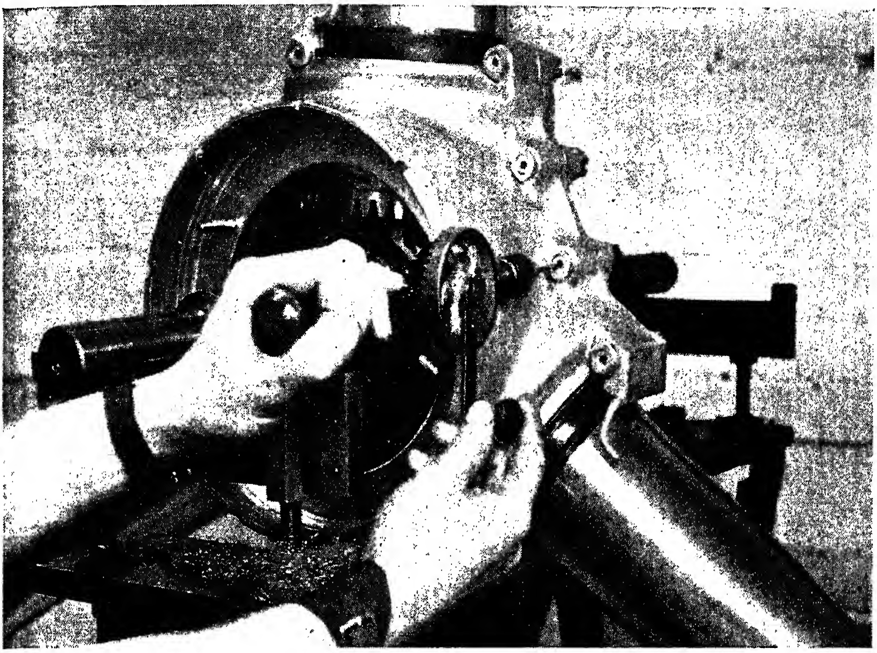


Fig. 46.—Lead wool of requisite amount is then drilled out if necessary to perfect the balance of assembly

ponent, such as a new blade, or the repair of damaged blades, that the compensation provided in the hollow barrel bolts is not sufficient to secure satisfactory balance, and additional facilities are therefore provided in the interior of the blades themselves.

Before dismantling such an airscrew, the lead in all the barrel bolts should be drilled out and the moment necessary to hold the lightest blade in the horizontal

Fig. 47.—Measurement taken in determining

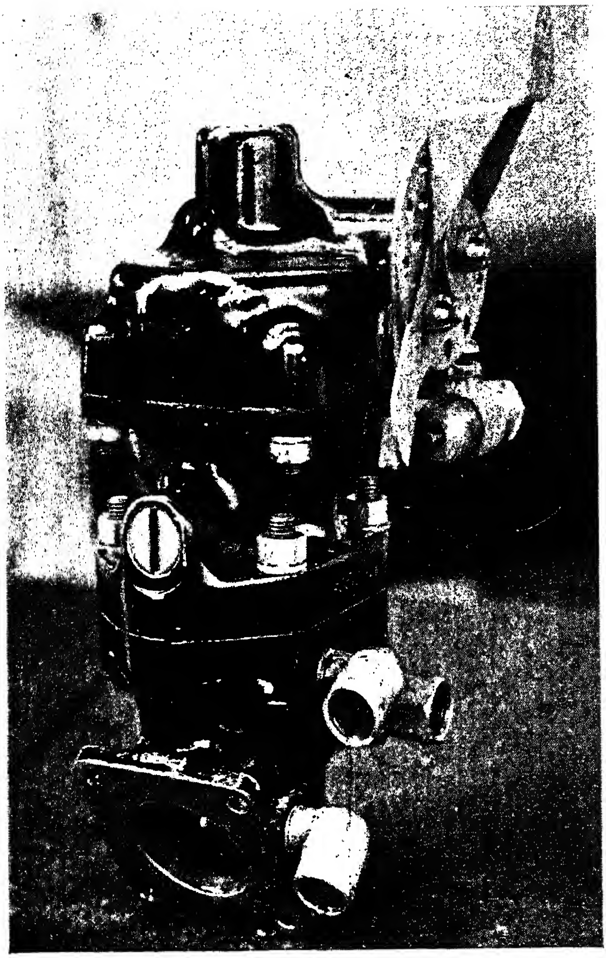


Fig. 48.—Constant speed control unit

position should be ascertained by hanging balancing washers at a given distance from the face of the barrel, according to the diagram and table given on page 41. The distances in this table represent the position of the *washer farthest from the hub centre, that is, the washer which will seat next to the blade plug face.* Thin string or wire may be used, encircling the blade to secure the washers approximately in the position they will occupy inside the blade, and when so secured the effect in the vertical position can also be tried without difficulty.

For errors in balance which do not exceed the amounts given in the table, washers up to twelve in number may be employed. When by this means a nearly true balance has been obtained, the blades on which the adjustment is to be made are observed and marked for identification with the number of washers required, so that no mistake can occur when the airscrew is dismantled.

The airscrew is then dismounted and dismantled according to the schedule given in previous paragraphs, and the blades on which the adjustment is required are removed from the spider.

The Simmonds nut is then unscrewed from the blade plug and the washers placed in position, the whole being again clamped up by the Simmonds nut, which is fitted with a fibre insert and is self-locking.

There is no occasion to withdraw the blade plug for these operations,

SHANK SIZE	BALANCING MOMENT oz.-ins.
1000	19
2000	23
3000	25
4000	29
5000	34
6000	42

BLADE BALANCING

Note: *The balancing moments are the values obtained with 12 washers. Size AGS. 160/H.*

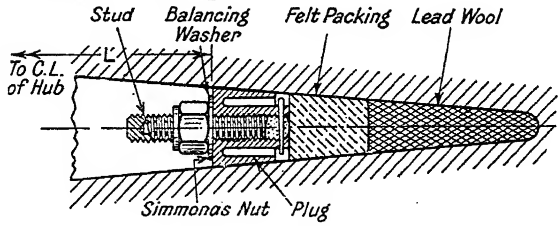


Fig. 49.—Blade balancing

1.—This balancing plug assembly is the same for 4000 and 5000 type airscrews. 2.—It replaces the old system of fixed plugs and cork. 3.—For servicing and repairing blades. Variations in balance up to the amount shown may be obtained by adding up to 12 AGS. 160/H washers. 4.—Finer degrees of adjustment may be obtained by mixing AGS. 160/H and AGS. 160/I washers.

and indeed it is preferable that it should not be disturbed.

The blades are then reassembled on the spider and the airscrew rebuilt and again put on the balancing ways to prove the correctness of the new adjustment.

Where for any reason the error in balance in any one blade exceeds the tabulated values in the table, the following procedure must be followed :

The additional moment required to obtain balance must be determined as already described, except that lead wool must be attached to the blade at a point equal to the length of the blade plug and felt packing wad beyond the given distance from the centre of the hub, that is, in approximately the position it will occupy inside the blade. The airscrew is then dismantled and the blade plug extracted from the blade on which the adjustment is to be made. The lead wool actually used to obtain the balance externally is then inserted and a wooden drift with slightly convex end is used to pack it tightly in position.

BALANCING TABLE

Shank Size	*No. of Blades*	*Dimension. Distance from centre of hub to outboard face of balancing washers (L)* *In.*
1,000	2	7·0
2,000	2	8·16
3,000	3	8·87
4,000	2	9·89
4,000	3	10·23
5,000	3	11·84
6,000	3	14·50

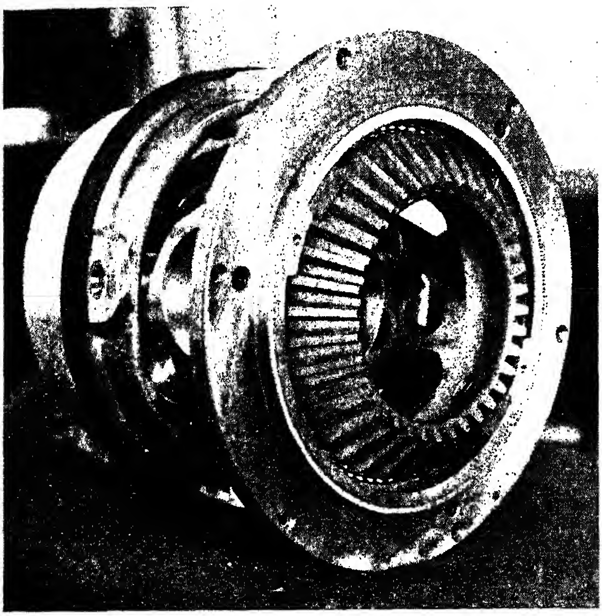


Fig. 50.—Piston and cam assembly—high pitch position. (Feathered)

Occasionally it may be found that already the blade has been weighted, and that there is not enough room to accommodate the amount of lead wool it is required to tamp into the bore, plus a minimum of one felt wad. In such circumstances it will probably be possible to effect balance by removing some portion of the lead wool from the other blades of the airscrew, so reducing their moment about the axis.

Similarly, this method of obtaining balance by removing part of the disposable weight from blades, blade plugs, or barrel bolts is equally applicable when making the smaller adjustments, and since it tends to reduce the total weight of the airscrew, should be practised whenever possible. The felt packing and blade plug are then replaced, and the airscrew is reassembled and put back on the balancing ways for final checking.

Having obtained as near perfect balance as possible by the foregoing means, a tolerance of 3-in. ounces may be applied when, if it holds the airscrew stationary or starts it turning in the opposite direction to that in which it was at first disposed to move, the airscrew is in satisfactory balance. The tolerance is most easily applied by rolling up a pellet of lead wool of roughly three-quarters of an ounce in weight and resting it on the edge of the barrel aperture about 4 in. from the axis of the blade. Alternatively, a piece of plasticine weighing three-quarters of an ounce may be made to adhere in any position on the barrel 4 in. from the centre to produce a similar effect.

AFTER BALANCING

When satisfactory balance has been obtained, the airscrew assembly is completed as follows:

(1) Remove airscrew from balancing stand and remount on the workbench arbor.

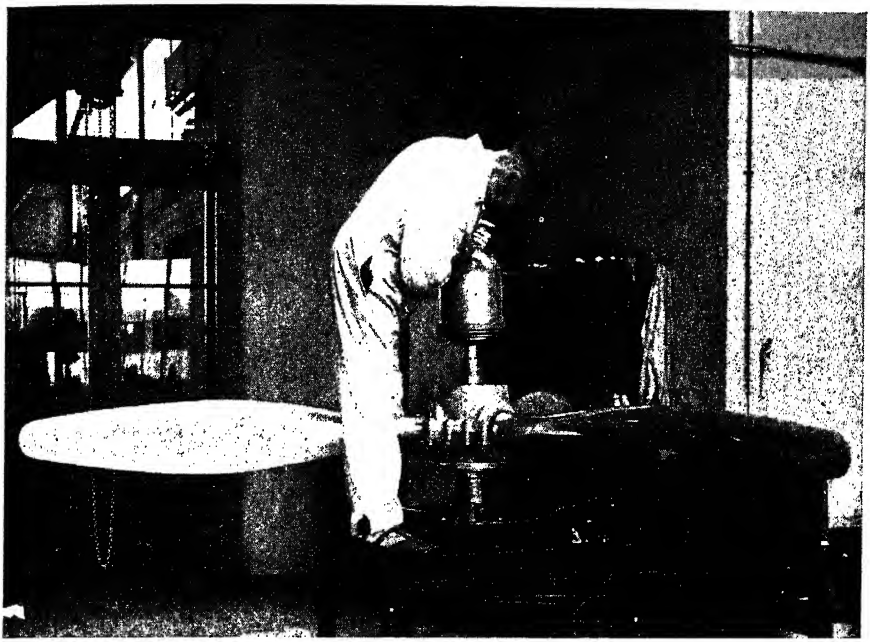


Fig. 51.—Installing dome on hub and hydromatic airscrew

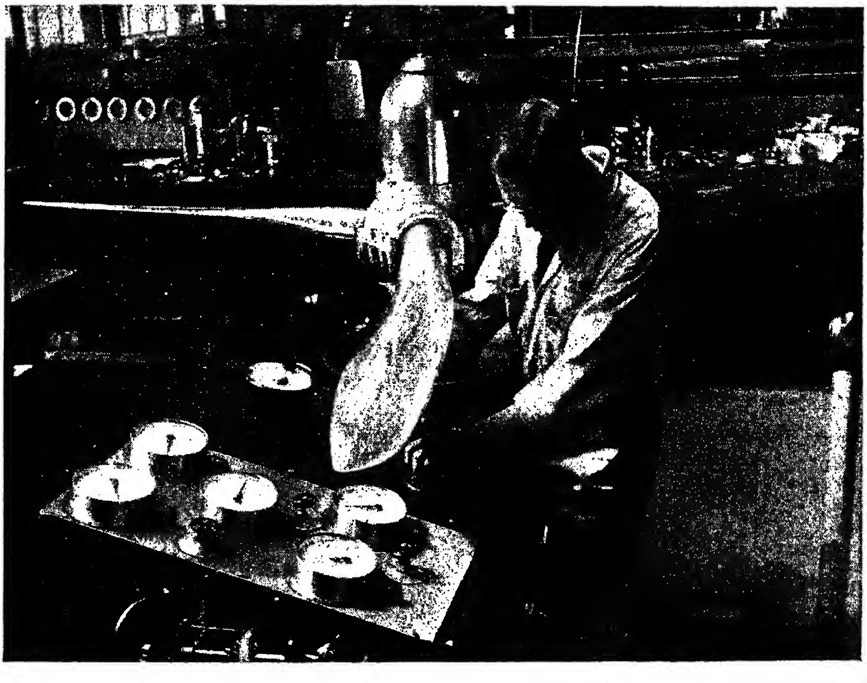


Fig. 52.—Airscrew on test machine

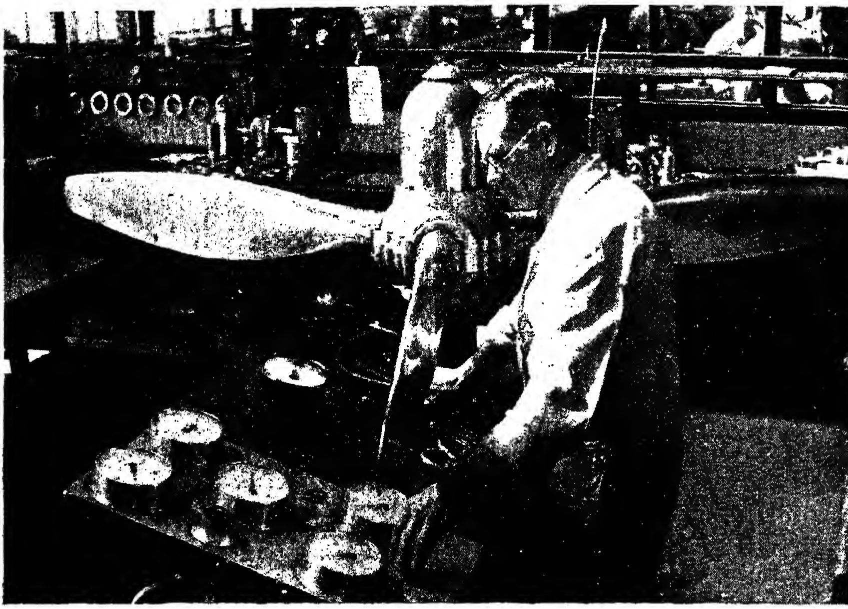


Fig. 53.—A FURTHER STAGE OF TESTING AIRSCREW ON MACHINE

(2) Dismantle the airscrew.

(3) Stamp all replacement parts according to their positions in the airscrew after balance has been obtained. This stamping should be done lightly with a $\frac{1}{16}$-in. type, or, and preferably, where the material is suitable, the numbers should be etched.

(4) Paint the whole of the metal components of the hub inside and out with lanoline emulsion.

(5) Assemble the rear half barrel and spider on the assembly mandrel, taking care that the spider arms are in line with the barrel apertures similarly marked.

(6) Remove greasing nipples from the spider.

(7) Assemble shim packs and packing plates on the spider.

(8) Place grease-retaining washers in position over spider arms.

(9) Fill up the bores of the blades to within 2 in. of the top with Mobilgrease No. 2 or equivalent, and press the blades home into position against packing plate.

(10) Replace greasing nipples and mount the barrel blocks in position on the spider. In the case of the third blade, it will be necessary to withdraw this blade from the spider arm about $\frac{1}{2}$ in. to permit the insertion of the packing block between the flanges of the counterweight brackets.

(11) Load the thrust-bearing roller cages with Mobilgrease No. 6 or its equivalent.

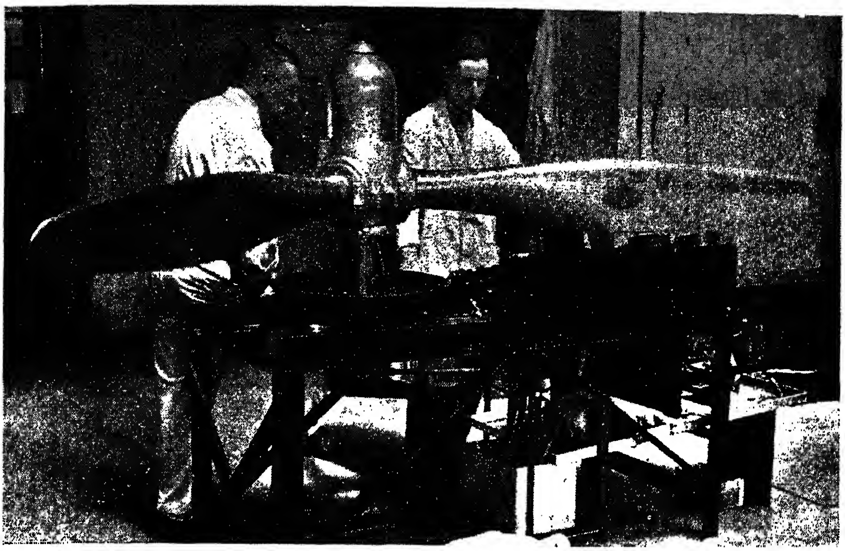


Fig. 54.—INSPECTOR CHECKING TEST FOR FULL FEATHERING

(12) Clip together blade thrust rings and races, and lift the bottom half of barrel into position, tapping home with rubber mallets.

From this point, assembly of the airscrew is completed in the same order as detailed under "Assembly After Overhaul."

(13) Finally, the airscrew is topped up with grease, which is forced through the nipples until no more can be inserted, and the counterweights are smeared internally with a little Mobilgrease No. 6.

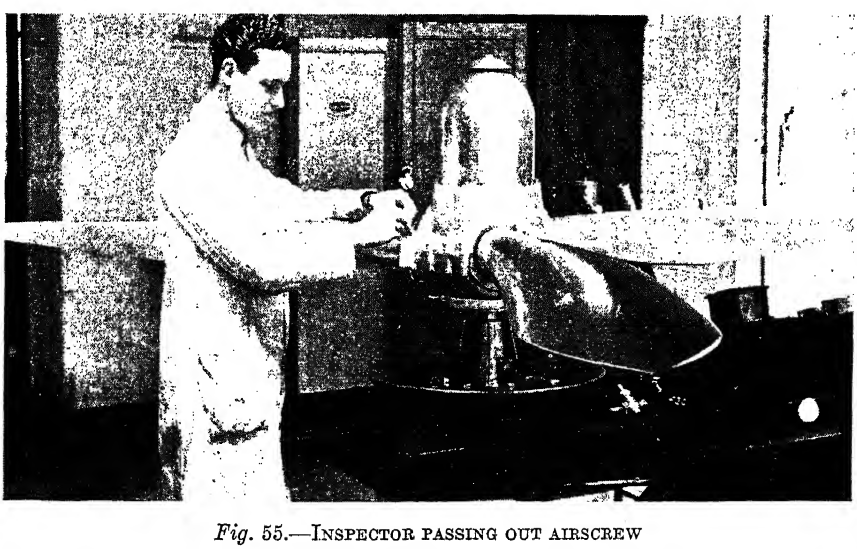


Fig. 55.—INSPECTOR PASSING OUT AIRSCREW

Fig. 55A.—De Havilland hydromatic full-feathering airscrew on the static test bed. (*By courtesy of the de Havilland Aircraft Co., Ltd.*)

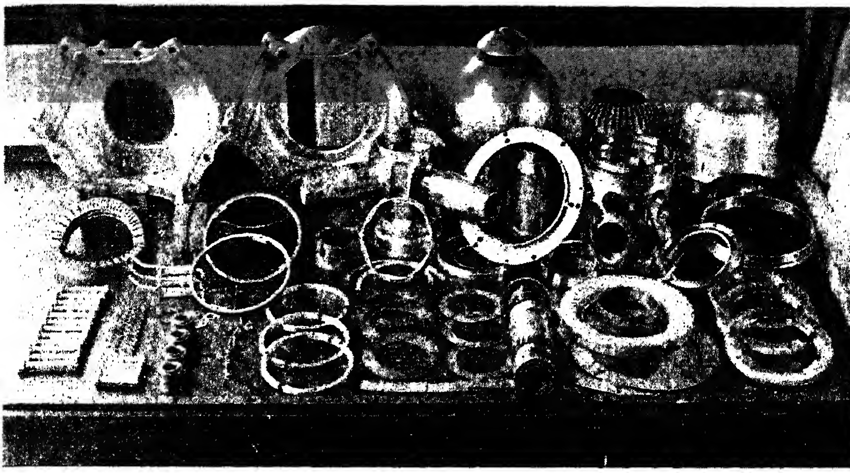


Fig. 56.—Complete component parts of hydromatic airscrew except blades

MAINTENANCE

Daily

(1) During running up of the engine prior to take-off on each flight check the pitch-change mechanism for proper operation (as described previously).

(2) Inspect the airscrew blades for external damage, and also all visible parts of the hub (as described in " Inspection of Parts ").

(3) Inspect the locking of all external screws and bolts.

(4) Examine specially any spinner or de-icer mountings for security ; and also the means of attachment of the spinner shell, i.e. bolts, rivets, etc., where these are visible.

Every Ten Hours of Flying

(1) Lubricate the blade-bushing bearings by means of the grease gun and extension through the greasing nipples. Mobilgrease No. 2 or equivalent must be used.

For cold-weather operation it is permissible to use a lighter lubricant, but before using any substitute, application should be made to the manufacturers.

After Forty Hours of Flying

(2) The counterweight bearings are greased, using Mobilgrease No. 6 or equivalent, which is inserted through the slot at the back of the counterweight, in which works the counterweight bearing shaft.

Grease may be inserted either with the fingers or with a spatula, but in the latter case care should be exercised that the end of the instrument is not allowed to bear upon the counterweight ball cage, which usually is found spanning the slot about the midpoint of its length.

First 100 Hours

Remove the airscrew from the aircraft and proceed with dismantling and inspection of parts.

GENERAL

Airscrews which have been involved in an accident, however slight, must always be submitted to inspection, and all steel components should preferably be examined on the Magna-Flux detector. If this method is not available, the airscrew should be returned to the manufacturers. A very close inspection must be made of all parts to ensure that no cracks or deformations have taken place. Particular attention must be given to all places where a change of section occurs. Hubs which have been twisted or sprung in such a manner as to upset the blade adjustment or perfect location of parts are not to be repaired, and must be replaced.

Caution.—No attempt must be made to straighten any distorted steel component.

In most cases damaged blades can be repaired, but it is important to note that repair work of this nature should only be handled by the manufacturers or by an authorised service station, and then only within the specified limit.

Care must be taken to record without delay all maintenance and overhaul particulars—including the whole of the identification marking of any replacement parts fitted—in the airscrew Log Book or History Sheet.

SCHEDULE OF FITS, CLEARANCES, AND REPAIR TOLERANCES FOR DE HAVILLAND VARIABLE-PITCH AIRSCREWS

Types 4/1, 5/1, 5/2, and 5/3

(1) The data regarding fits and clearances are specified under four headings, i.e. "Dimensions, new," "Permissible worn dimension," "Clearance, new," and "Permissible worn clearance."

(2) All dimensions are given in inches and decimals of an inch, together with a fractional suffix. The fractional suffix represents that fraction of a thousandth of an inch by which the actual dimension exceeds the decimal figure quoted. Thus a dimension given as $0{\cdot}531\frac{2}{10}$ in. when written in full would be 0·5312 in.

(3) The figures in the column "Dimensions, new," are the drawing sizes to which parts are made. These dimensions are given in limit form, and represent the minimum and maximum sizes to which parts may be accepted when new, as for example, $\dfrac{0{\cdot}531\frac{2}{10}}{0{\cdot}531\frac{7}{10}}$ quoted for bearing shaft bushing bore.

(4) The difference between the minimum and maximum dimensions quoted in paragraph 3 is known as the manufacturing tolerance. This tolerance is necessary as an aid to manufacture, and its numerical value is an expression of the accuracy required by the design.

It may also be considered as a numerical expression of the desired quality of workmanship. For the bearing shaft example referred to in paragraph 3, the tolerance is 0·000½ in.

(5) The dimensions in the column "Permissible worn dimension" represent the limits of size to which parts may be worn and refitted for a further period of service.

Note.—These dimensions have been so fixed that the components are fit for the full period of further service, which is normally permitted between complete overhauls. When, however, parts are found, during complete overhaul, to be worn beyond the limits laid down, they must be discarded as unserviceable.

(6) In the column "Clearance, new," are given the minimum and maximum working clearances obtainable with new parts when assembled together; these are functions of the minimum and maximum sizes of mating parts given in the "Dimensions, new" column. For example, if a new bearing shaft machined to the minimum diameter $0{\cdot}530\frac{2}{10}$ in. is assembled with a new bearing shaft bushing, having a bore machined to the maximum size, $0{\cdot}531\frac{7}{10}$ in., the resulting working clearance will be 0·001½ in. L; similarly, if a new bearing shaft machined to its maximum diameter $0{\cdot}530\frac{7}{10}$ in. is assembled with a new bearing shaft bushing machined to the minimum size, $0{\cdot}531\frac{2}{10}$ in., the resulting working clearance will be 0·000½ in. L.

Note.—Under the columns "Clearance, new" and "Permissible worn clearance" the letters L and T represent Loose and Tight respectively.

(7) The "Permissible worn clearance" is the limit of working clearance permissible between any two parts assembled together.

(8) If a male member, worn to the minimum diameter, is assembled with a corresponding new female part, machined to the minimum drawing dimension, the resulting working clearance between the two parts will, in most cases, correspond with the maximum permissible worn clearance. Similarly, if a female part, worn to the maximum permissible bore diameter, is assembled with a corresponding male part, machined to the maximum drawing dimension, the resultant clearance will be the same. For example:—

New bearing shaft bush having bore to minimum drawing limit	$0{\cdot}531\frac{2}{10}$ in.
Bearing shaft worn to permissible diameter . .	$0{\cdot}528\frac{7}{10}$ in.
Resultant clearance	0·002½ in. L.
Bearing shaft bush worn to maximum bore diameter, i.e. permissible size.	$0{\cdot}533\frac{2}{10}$ in.
Bearing shaft having a diameter to maximum drawing dimension	$0{\cdot}530\frac{7}{10}$ in.
Resultant clearance	0·002½ in. L.

SECTION I.

GENERAL ASSEMBLY

FIG. 57.

Ref. No. on diagram.	*V.P. airscrew type.*	*Parts and description.*	*Dimensions, new.*	*Permissible worn dimension.*	*Clearance, new.*	*Permissible worn clearance.*	*Remarks.*
			in.	in.	in.	in.	
1	4/1	Blade bush bore . .	$\frac{2{\cdot}063\frac{8}{10}}{2{\cdot}064\frac{8}{10}}$	$2{\cdot}067\frac{8}{10}$			
		Spider diameter . .	$\frac{2{\cdot}061\frac{8}{10}}{2{\cdot}061\frac{8}{10}}$	$2{\cdot}067\frac{8}{10}$			
		SPIDER IN BLADE BUSH (SMALL)			$\frac{0{\cdot}002\ L}{0{\cdot}003\ L}$	0·006 L	
	5/1, 5/2 & 5/3	Blade bush bore . .	$\frac{2{\cdot}126\frac{8}{10}}{2{\cdot}126\frac{8}{10}}$	$2{\cdot}130\frac{8}{10}$			
		Spider diameter . .	$\frac{2{\cdot}123\frac{8}{10}}{2{\cdot}124\frac{8}{10}}$	$2{\cdot}120\frac{8}{10}$			
2	4/1	Blade bush bore . .	$\frac{2{\cdot}501\frac{8}{10}}{2{\cdot}502\frac{8}{10}}$	$2{\cdot}505\frac{8}{10}$			
		Spider diameter . .	$\frac{2{\cdot}499\frac{8}{10}}{2{\cdot}499\frac{8}{10}}$	$2{\cdot}495\frac{8}{10}$			
		SPIDER IN BLADE BUSH (LARGE)			$\frac{0{\cdot}002\ L}{0{\cdot}003\ L}$	0·006 L	
	5/1, 5/2 & 5/3	Blade bush bore . .	$\frac{2{\cdot}626\frac{8}{10}}{2{\cdot}627\frac{8}{10}}$	$2{\cdot}630\frac{8}{10}$			
		Spider diameter . .	$\frac{2{\cdot}624\frac{8}{10}}{2{\cdot}624\frac{8}{10}}$	$2{\cdot}620\frac{8}{10}$			

SECTION I. GENERAL ASSEMBLY—*Continued* FIG. 57.

Ref. No. on diagram.	*V.P. airscrew type.*	*Parts and description.*	*Dimensions, new.*	*Permissible worn dimension.*	*Clearance, new.*	*Permissible worn clearance.*	*Remarks.*
			in.	in.	in.	in.	
3	4/1, 5/1, 5/2 & 5/3	Shim plate bore . .	4·250/4·252	4·258	0·005 L/0·009 L	0·013 L	
		SPIDER SPIGOT IN SHIM PLATE BORE. Spider spigot diameter .	4·243/4·245	4·237			
4	4/1	Barrel bore . . .	4·812½/4·813½	4·843	0·000½ L/0·006½ L	0·031 L	
		Barrel chafing ring diameter . . .	4·807/4·812	4·781½			
	5/1, 5/2 & 5/3	BARREL CHAFING RING IN BARREL. Barrel bore . . .	5·500/5·501	5·531			
		Barrel chafing ring diameter . . .	5·495/5·500	5·469	0·000/0·006 L		
5	4/1	Barrel bore . . .	6·750/6·755	6·762	0·002 T/0·005 L	0·010 L	
		Shim plate and shim plate chafing ring diameter .	6·750/6·752	6·740			
	5/1, 5/2 & 5/3	SHIM PLATE AND SHIM PLATE CHAFING RING IN BARREL . Barrel bore . . .	7·250/7·255	7·262			
		Shim plate and shim plate chafing ring diameter .	7·250/7·252	7·240			

 GENERAL ASSEMBLY—*continued* FIG. 57.

Ref. No. on diagram.	*V.P. airscrew type.*	*Parts and description.*	*Dimensions, new.*	*Permissible worn dimension.*	*Clearance, new.*	*Permissible worn clearance.*	*Remarks.*
			in.	in.	in.	in.	
6	4/1	Cylinder base bore . .	3·625 / 3·627	3·637			
		Piston diameter . .	3·615 / 3·617	3·605			
	5/1, 5/2 & 5/3	PISTON IN CYLINDER BASE BORE.			0·008 L / 0·012 L	0·020 L	
		Cylinder base bore . .	4·187 / 4·189	4·199			
		Piston diameter . .	4·177 / 4·179	4·167			
7	4/1, 5/1, 5/2 & 5/3	Fit thicker shim plate when torque loading falls below 50 ft./lbs.					
8	4/1, 5/1, 5/2 & 5/3	*Spider—Cone Seat* . .					When wear shown on cone seat exceeds 20 per cent. of total area, regrind or lap seat.
9	4/1	*Internal diameter* . .	6·750 / 6·755	6·770			Maximum grinding allowance.
	5/1, 5/2 & 5/3	*Earrel* *Internal diameter* . .	7·250 / 7·255	7·270			
10	4/1, 5/1, 5/2 & 5/3	*Cylinder*—Bore . . .	4·500 / 4·502	4·531			Bore must be of fair contour without depressions or sharp edges.

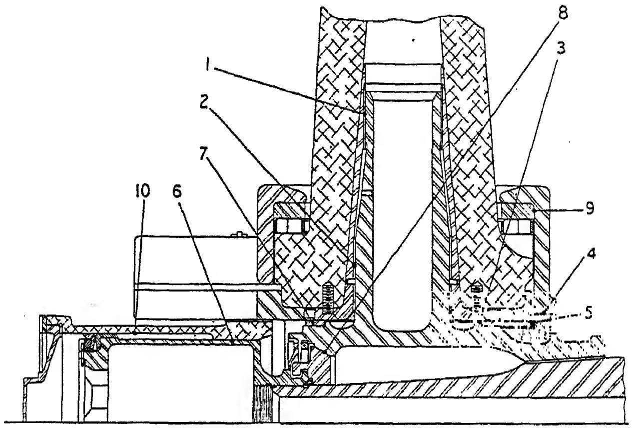


Fig. 57 (*right*).—GENERAL ASSEMBLY

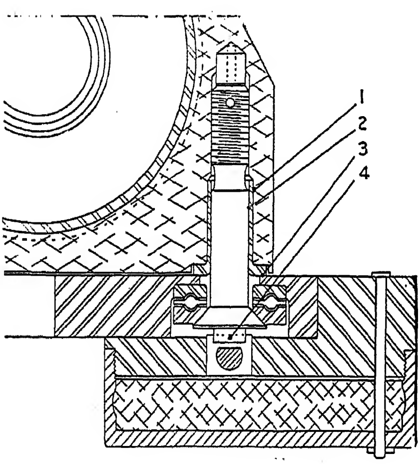


Fig. 58 (*left*).—THRUST RACE ASSEMBLY

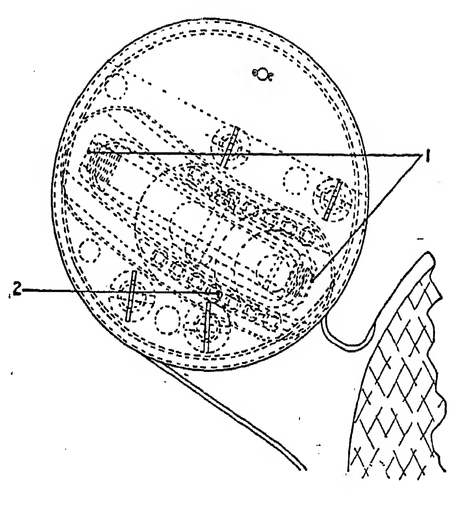


Fig. 59 (*right*).—COUNTERWEIGHT, COUNTERWEIGHT BRACKET, AND THRUST RACE ASSEMBLY

SECTION II.

THRUST RACE ASSEMBLY

FIG. 58.

Ref. No. on diagram.	*V.P. airscrew type.*	*Parts and description.*	*Dimensions, new.*	*Permissible worn dimension.*	*Clearance, new.*	*Permissible worn clearance.*	*Remarks.*
			in.	in.	in.	in.	
1	4/1, 5/1, 5/2 & 5/3	Cylinder bore	$\frac{0{\cdot}624\frac{1}{2}}{0{\cdot}625\frac{1}{2}}$	$0{\cdot}627\frac{1}{2}$	$\frac{0{\cdot}000}{0{\cdot}002}$ T	0·001 L	
		BEARING SHAFT BUSHING IN CYLINDER. Bearing shaft bushing diameter.	$\frac{0{\cdot}625\frac{1}{2}}{0{\cdot}626\frac{1}{2}}$	$0{\cdot}623\frac{1}{2}$			
2	4/1	Bearing shaft bushing bore.	$\frac{0{\cdot}521\frac{2}{10}}{0{\cdot}531\frac{7}{10}}$	$0{\cdot}533\frac{2}{10}$			
	5/1, 5/2 & 5/3	BEARING SHAFT IN BUSH			$\frac{0{\cdot}000\frac{1}{2}\text{ L}}{0{\cdot}001\frac{1}{2}\text{ L}}$	$0{\cdot}002\frac{1}{2}$ L	
		Bearing shaft diameter	$\frac{0{\cdot}530\frac{2}{10}}{0{\cdot}530\frac{7}{10}}$	$0{\cdot}528\frac{7}{10}$			
3	4/1, 5/1, 5/2 & 5/3	BEARING SHAFT BUSHING FLANGE AND COUNTERWEIGHT BRACKET.			$\frac{0{\cdot}000}{0{\cdot}003}$ (clearance)		0·031
4	4/1, 5/1, 5/2 & 5/3	STOP NUTS WILL WEAR A SEAT ON HEAD OF COUNTER-WEIGHT BEARING SHAFT.					No replacement necessary.

COUNTERWEIGHT, COUNTERWEIGHT BRACKET, AND THRUST RACE ASSEMBLY

SECTION III. FIG. 59.

Ref. No. on diagram.	*V.P. airscrew type.*	*Parts and description.*	*Dimensions, new.*	*Permissible worn dimension.*	*Clearance, new.*	*Permissible worn clearance.*	*Remarks.*
			in.	in.	in.	in.	
1	4/1	Counterweight slot . .	$\frac{3{\cdot}417}{3{\cdot}421}$	3·435	$\frac{0{\cdot}002\ L}{0{\cdot}010\ L}$	0·020 L	
	5/1	COUNTERWEIGHT ADJUSTING SCREW (END CLEARANCE) IN COUNTERWEIGHT SLOT.					
	5/2 & 5/3	Counterweight adjusting screw.	$\frac{3{\cdot}411}{3{\cdot}415}$	3·397			
2	4/1, 5/1, 5/2 & 5/3	COUNTERWEIGHT BEARING CAGE.					Scrap cage if cracked or if more than $\frac{1}{3}$rd of the balls are badly worn.

TOLERANCES OF SIMILARITY

	Type 4/1.		*Types* 5/1, 5/2, 5/3.	
	Inboard of 30-in. station.	*30-in. station to tip incl.*	*Inboard of 36-in. station.*	*36-in. station to tip incl.*
	in.	in.	in.	in.
Blade width	± 0·070	± 0·070	± 0·080	± 0·070
Blade thickness	± 0·040	± 0·040	± 0·050	± 0·040
Edge alignment	± 0·070	± 0·070	± 0·070	± 0·070
Face alignment	± 0·070	± 0·070	± 0·070	± 0·070
Template fit	± 0·040	± 0·030	± 0·050	± 0·030
Blade angle	± 0·5°	± 0·20°	± 0·5°	± 0·20°
Longitudinal location of stations	± 0·015	± 0·015	± 0·015	± 0·015
Blade length	± 0·070		± 0·070	

(9) On page 53 will be found three diagrams which are intended to facilitate reference to the various points at which wear occurs. All points of wear in each assembly are shown in the appropriate diagram, and each bears a numerical reference. These reference numbers correspond with the reference numbers quoted in column 1 of the appropriate section of the schedule, against those components between which wear occurs or in which distortion is liable to take place.

(10) Parts worn beyond the limits given in this schedule should be returned to the manufacturers, who will, as a rule, be able to restore them for further service by fitting oversize or undersize complementary parts to provide the original working clearances.

SCHEDULE OF REPAIR TOLERANCES OF BLADES FOR VARIABLE-PITCH AIRSCREWS

TYPES 4/1, 5/1, 5/2 and 5/3

1. Repair Tolerances

All nicks, dents and scratches on blades must be erased with a smooth file and smoothed out with fine emery cloth—from being sharp cornered indentations they must be made into smooth rounded depressions.

Caution.—Blade repair must not be undertaken where limitations or damage given in following table are exceeded :—

Shank must be within drawing tolerances.
Inner $\frac{2}{3}$ of blade, X must not exceed 0·025W.
Inner $\frac{2}{3}$ of blade, Y must not exceed ·025T.

Outer $\frac{1}{3}$ of blade, X must not exceed ·050W.

Outer $\frac{1}{3}$ of blade, Y must not exceed ·050T.

Outer 12 in. of blade, X must not exceed ·100W.

Outer 12 in. of blade, Y must not exceed ·100T.

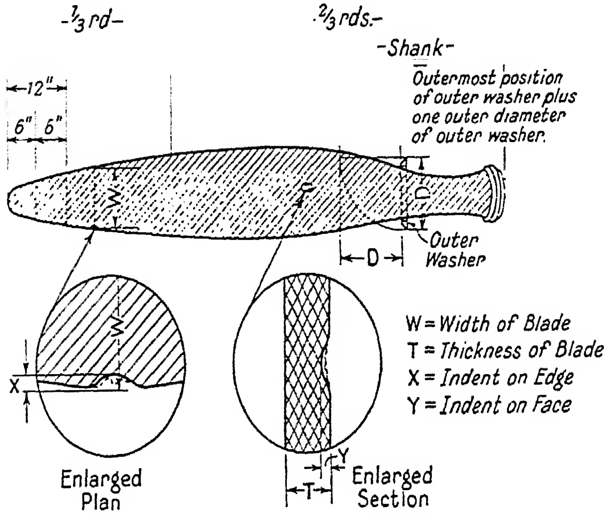


Fig. 60.—REPAIR TO BLADES

Outer 6 in. of blade may be repaired as required.

Where these limits of damage are exceeded, it will normally be possible to restore the blade to a new drawing number, for which purpose it should be returned to the manufacturers.

2. Tolerances of Similarity

It will often occur that blades returned to the manufacturers for repair will require to be reshaped along the edges or at the tip, and where the damage is extensive the blade will be restored to a new drawing number and will then only be suitable as spare on a different type of airscrew—usually of less diameter.

Where, however, the damage is only slight, the blades will be restored at, as nearly as possible, the original dimensions, in order that they may be held as spare and used in the type airscrew for which they were designed originally.

Such blades will be adjusted for balance as described in the section on balancing, but in order that they may be also in aerodynamic balance it is necessary to limit the amounts by which they vary from the other blades in their similar dimensions.

These tolerances are given in tabulated form on the previous page, and wherever possible spare blades within these tolerances should be fitted, but should they not be available then the larger blades in the airscrew must be refinished to the size of the smallest within the similarity tolerance.

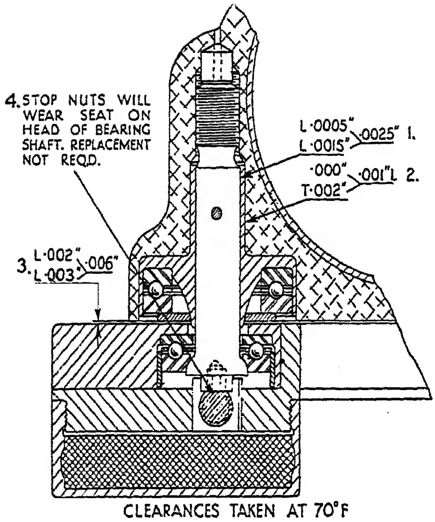


Fig. 61.—Counterweight bearing shaft

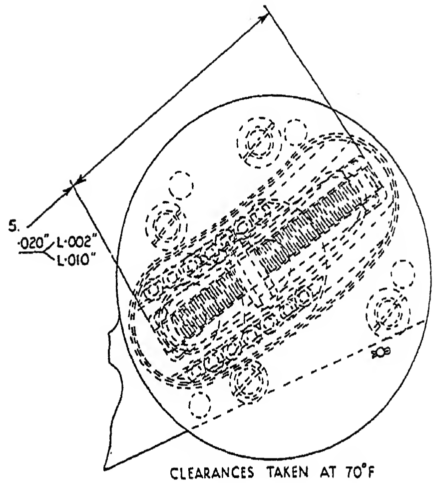


Fig. 62.—Counterweight adjusting screw

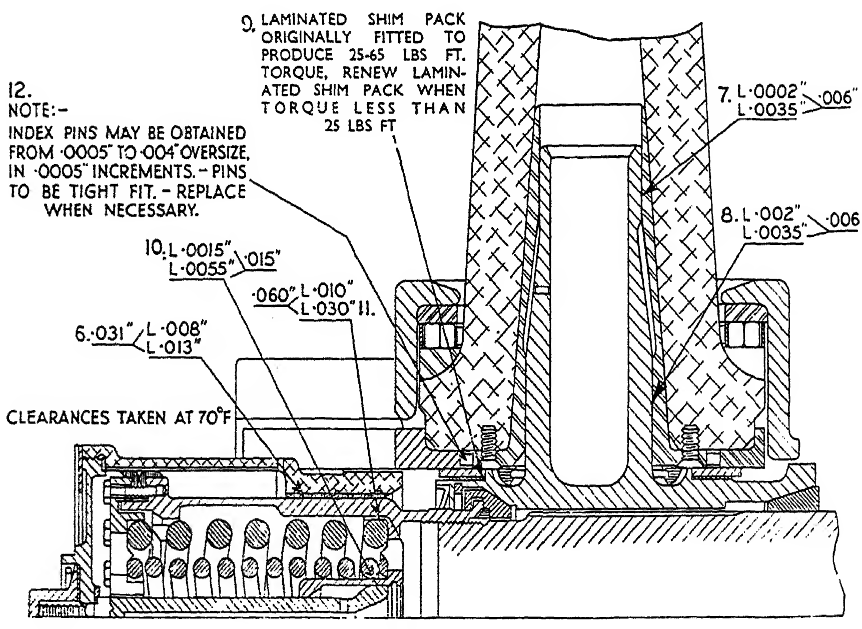


Fig. 63.—Cylinder base, blade bush, and spider bearing, etc.

CLEARANCE CHART (5000 20° AIRSCREWS)
(Spring- and Pressure-operated Types. See Figs. 61, 62, and 63)

	Specified In.	*Permissible In.*
(1) Counterweight Bearing Shaft and Counterweight Bearing Shaft Bush . . .	L ·0005 L ·00015	·0025
(2) Cylinder Bearing Shaft Bush, fit in Cylinder	·000 T ·002	L ·001
(3) Counterweight Bearing Shaft, Thrust Washer and Counterweight Bracket .	L ·002 L ·003	·006
(4) Stop nuts will wear seat on head of Counterweight Bearing Shaft . . .	(Replacement not required)	
(5) Counterweight Adjusting Screw end clearance	L ·002 L ·010	·020
(6) Piston and Micarta bushing in Cylinder base	L ·008 L ·013	·031
(7) Blade Bush and Spider Bearing (small) .	L ·002 L ·0035	006
(8) Blade Bush and Spider Bearing (large) .	L ·002 L ·0035	·006
(9) Laminated Shim Pack, originally fitted to produce 25–65 lbs./ft. torque. Renew laminated shim pack when torque less than 25 lbs./ft.	—	—
(10) Draw Bolt Head and Spring Bucket	L ·0015 L ·0055	·015
(11) Spring Bucket and Piston Bore .	L ·010 L ·030	·060

NOTE.—Index pins may be obtained from ·0005 in. to ·004 in. oversize in ·0005-in. increments—pins to be tight fit—replace when necessary. All clearances taken at 70° F.

THE DE HAVILLAND CONTROLLABLE PITCH AND HYDROMATIC AIRSCREWS

OPERATION, CONTROL, AND INSTALLATION

IN this type of airscrew rigid blades are employed which turn about their longitudinal axes in order to change pitch.

An outer member—the barrel—envelops the blade roots, and is designed to absorb the centrifugal pull of the blades when the airscrew is rotating.

In many designs this component is splined to the engine shaft and is also required to transmit the driving torque to the blades, but in the de Havilland airscrew this torque is taken by an internal member known as the spider, which is provided with arms on which the blades are free to turn.

The airscrew is mounted on the forward end of the airscrew shaft, and is operated by hydraulic pressure from the engine oil system, either directly or through a boost pump, and by counterweights which apply centrifugal force to move the blades in the opposite direction to that in which they move under pressure.

Depending upon the range of blade movement, certain types employ spiral springs to assist the centrifugal action of the counterweight—such a type is described in this article—whilst all types can be employed in conjunction with the governor unit to give constant speed control in flight.

By employing engine oil pressure to change the pitch of the blades in one direction and the centrifugal effort of counterweights to reverse the motion, a simple and robust design of pitch-change mechanism has been devised which has few moving parts and is not liable, therefore, to derangement.

The response of hydraulic mechanism is much quicker than that of other types ; moreover, it is less liable to functional failure than airscrews which depend on extraneous sources of power or intricate mechanisms to effect pitch change, for it will be apparent that both oil pressure and centrifugal force are fundamental in origin, and must be available whilst the engine remains effective.

OPERATION AND CONTROL

On all high-powered British aero engines, and on many types developing only medium or low power, provision is now made for the supply of

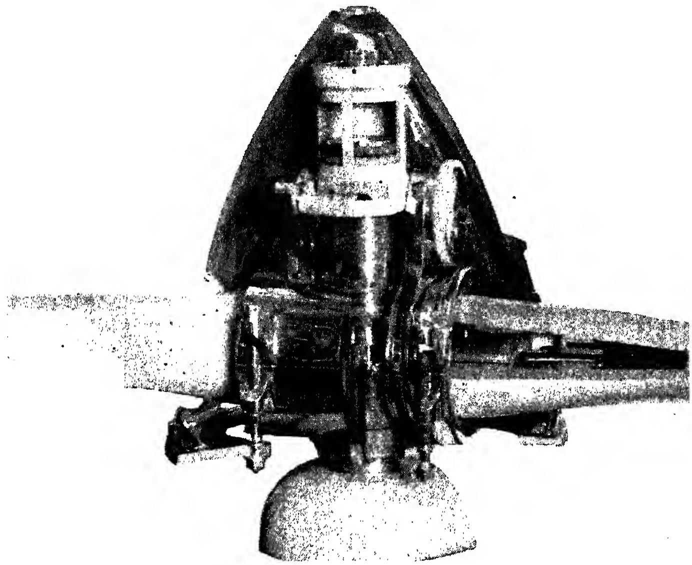


Fig. 1.—Cut-away mechanism of the De Havilland 1,000-size constant-speed airscrew, showing cylinder, counterweights, blade-root design, barrel, and spider

oil under pressure through the airscrew shaft, to furnish the power required to operate the airscrew.

This oil is admitted to, or released from, the airscrew through a two-position valve or cock, which is mounted in a convenient position on the crankcase, and which is operated by the pilot through the agency of a control lever or a " push-pull " knob.

In accordance with general usage, the control is moved back or " outwards " for the oil inlet position (fine pitch position of the blades for take-off and climb), and forward or " inwards " for the oil drain position (coarse pitch position of the blades for cruising, etc.).

Where the airscrew is fitted for constant speed operation, the " two-position " valve is moved by an external governor.

When the cockpit control is pulled back, the operating valve is moved into a position where oil is admitted into the airscrew under pressure from the engine oil system. The oil flows through a collector ring into the shaft, and thence into the pitch operating cylinder. Here it is trapped by the cylinder head, and builds up pressure which forces the cylinder to slide forward on the fixed piston. This causes the bearing shafts, which are located in the large flange at the rear end of the cylinder, and whose outer ends hold the special ball bearings, to slide in the cam slots in the counterweight brackets. As these bearings, which consist

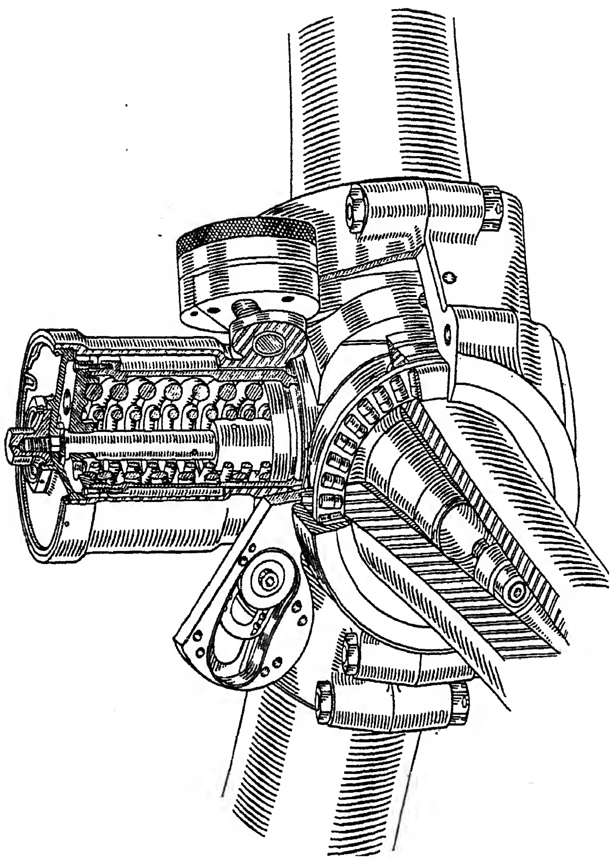


Fig. 2.—Perspective sketch in part section

of a cap race and a ball cage, roll along the cam slot, they move the counterweights inwards towards the airscrew shaft axis against centrifugal force.

The counterweight is located on the arm of the counterweight bracket, hence the whole counterweight bracket rotates inwards, and since it is attached by four index pins to the blade bushing, the blade is turned into the low pitch position. *Thus the oil pressure causes the airscrew blades to go into the low or fine pitch position by forcing the cylinder to slide forward on the piston.*

When the cockpit control is pushed forward, the operating valve is moved into a position which allows the oil to drain back from the airscrew into the engine crankcase. As soon as the engine oil pressure is released, from the cylinder, a reversal of the sequence described above takes place and the centrifugal force of the counterweights causes the counterweight brackets to move outwards, away from the airscrew shaft axis. The resultant reaction on the ball bearings in the cam slots forces the cylinder to slide backwards along the piston towards the high-pitch position. This action impels the oil inside the cylinder to flow back into the airscrew shaft and thence through the collector ring into the crankcase.

Thus, the release of the oil pressure in the cylinder allows centrifugal force to turn the blades into the high or coarse pitch position.

Other Functions of Component Parts

The piston acts as a retaining nut to hold the airscrew on the airscrew shaft, and oil leakage between it and the cylinder is prevented by a cup

leather, which is backed up by a second cup leather whose principal function is to guide the cylinder when moving along the piston. These leathers are secured by the piston head, which also forms the outer abutment for two spiral springs, and which in turn is held in position by a spigot and sixteen hexagonal-headed screws. The piston head, furthermore, is drilled with a number of holes to permit the passage of oil into the cylinder, and is provided at its centre with a clearance hole through which passes the spring draw bolt.

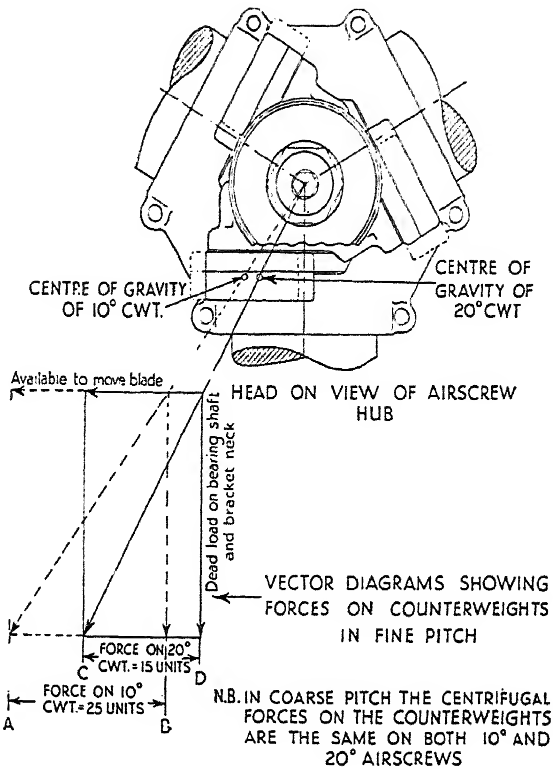


Fig. 3.—VECTOR DIAGRAM

At the inner end of the piston, resting upon a flange machined internally, is the spring cup or bucket which is arranged with a central bore in which works the head of the draw bolt, and which allows the cylinder to move for approximately half its stroke before picking up the spring load. In action a constant oil pressure is applied to overcome the centrifugal effort of the counterweights, which is at a maximum in the coarse pitch position, and falls off progressively as the counterweights approach a plane passing through the axis of rotation. For half the stroke, therefore, the whole of this pressure is available to overcome the centrifugal force, and as this latter becomes less in magnitude, the spring draw bolt picks up and compresses the two spiral springs, thus storing up energy which is available in the reverse direction to assist the counterweight's move from the fine pitch position.

In the diagram (Fig. 3) the forces employed in moving the counterweight are shown graphically, and it will be seen that the centrifugal force acting along a line through the axis of rotation and the centre of mass of the counterweight may be split up into two components, only one of which is available to move the counterweight, whilst the other is taken up as a direct pull on the counterweight bearing shaft.

There is, therefore, a limit to the size of the counterweight beyond which it is desirable to obtain further increases of useful force by means of springs, thereby avoiding increased weight and excessive centrifugal loadings on the brackets which might interfere with the smooth action of the pitch-changing mechanism.

Furthermore, the effect of increasing the travel of the counterweight to permit of a 20° pitch range is to bring the centre of mass of the counterweight so much nearer the plane containing the axis of the airscrew that the centrifugal force available to move the counterweight diminishes, in the ratio AB to CD. Where, in certain circumstances, the aerodynamic reaction on the blade is opposed to movement towards the coarse pitch position, this diminution of effort might retard the airscrew blades starting towards coarse pitch, and it is to this purpose that the stored-up energy in the springs is applied immediately the oil pressure is released. At half stroke the counterweights are sufficiently far removed from the plane passing through the axis of rotation to continue their travel towards the coarse pitch position without further assistance.

Airscrews of 20° pitch range and above are fitted with this spring and pressure mechanism, but for smaller-pitch ranges, and particularly in 15° airscrews, it will often occur that the counterweights alone will effect change of pitch positively and without hesitation, and in such cases the spiral springs will not be included in the airscrew, which then will be modified slightly as to piston arrangement.

Whilst the thrust and torque reactions on the blade are taken up mainly by the blade bushing on the arm of the spider and by the blade thrust bearing, some part is taken up by the spider packing plate, which serves to back up the outer portions of the blade end. The spider packing plates are made to a standard thickness in "oilite" bronze, a material which is self-lubricating, and is used to reduce friction and the "pick-up" wear and tear which occurred in this position with the hardened type of steel shimplate.

The adjustment required to obtain a pre-loading on the blade—torque loading—which is necessary to ensure that, whilst the blade is firmly held, it will be free to move to change pitch at speed, is obtained by fitting a shim of suitable thickness behind the packing plate where it seats on the spider.

In this type of airscrew the flanges on the spider behind the packing plate are machined concentric with the spider arm to provide a seating for three packing blocks—one between each pair of spider arms—which support the barrel.

Internal lubrication is provided by grease nipples between each pair of spider arms reached through coincident holes in the packing blocks and rear half of the barrel.

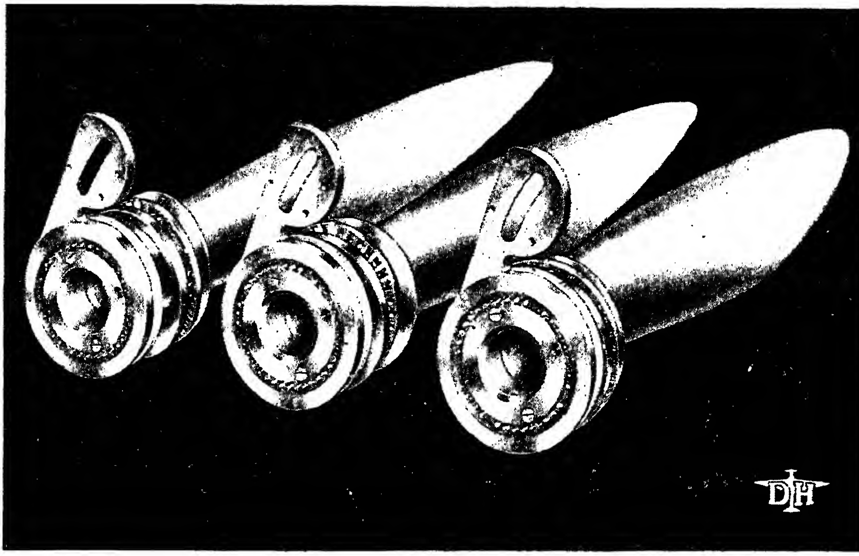


Fig. 4.—COUNTERWEIGHT BRACKETS MOUNTED ON BLADE ENDS SHOWING BASE-SETTING ADJUSTMENT AND THRUST RACES

Base Setting of Airscrew

The base setting of the airscrew blades is obtained by the means provided for attaching the counterweight brackets to the blade ends. The counterweight bracket fits around the outside of the blade bushing, and is held from end motion by the spider packing plate and the blade end. The inside circumference of the counterweight bracket has forty semicircular slots, and the blade bushing thirty-six similar slots, an arrangement which permits the insertion of four index pins, spaced 90° apart, where the two sets of semicircular slots on the counterweight bracket and on the blade bushing form four complete holes. This permits indexing the counterweight bracket relative to the blade in steps of 1°. Three of these slots on the counterweight bracket, and three on the blade bushing, are marked with three consecutive numbers to indicate positioning, e.g. 34°, 35°, 36°. Alterations of basic pitch angle settings in any required direction are made with reference to these markings.

Counterweight Adjusting Mechanism

In the counterweight is fitted the pitch adjusting screw, which is accommodated in a slot machined in the counterweight, and is prevented from turning by a dowel or pin which passes through the adjusting screw and locates in recesses at the side of the slot. The adjusting screw carries a square nut at each end which fits the slot, and can therefore be adjusted by quarter turns, whilst the counterweight bearing shaft is provided with an extension on the head, which bears against the undersides of these nuts

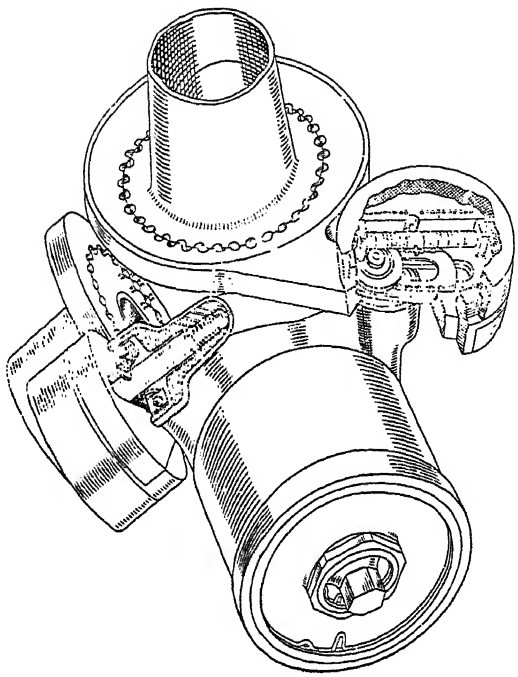


Fig. 5.—Skeleton assembly of counterweight brackets and blade bushings to show basic and counterweight settings in situ

and so limits the cylinder travel in both coarse and fine pitch positions.

Thus, the position of these nuts determines the angle through which the blades may turn in changing pitch, and adjustment is made by unscrewing the counterweight cap, removing the adjusting screw, and turning the nuts to the required angles in both coarse and fine pitch positions, against a scale stamped on the counterweight. This provision, together with the base setting arrangement of the airscrew, enables any desired coarse and fine pitch angle to be selected within the range for which the airscrew is designed.

To give rigidity to the adjusting screw, and to prevent it canting in the counterweight, additional stop nuts are assembled wherever they can be screwed on full thread without disturbing the settings of the two nuts controlling the pitch range.

Blade Angle Adjustment

Fig. 7 illustrates a case in which the base setting of the counterweight bracket is 34° as indicated by the position of the index pins. The blade angle at the 42-in. station is ascertained by subtracting the degree graduation opposite the face of the adjusting nuts, as follows: coarse pitch = base setting 34° minus 1° = 33°; fine pitch = base setting 34° minus 18° = 16°. The blade angle settings in degrees indicated by the position of the counterweight adjusting nuts, together with the base setting figure stamped on the lead plug inserted for the purpose in the counterweight, should be recorded in the Airscrew History Sheet or Log Book.

Care should be taken, when adjusting the stop nuts, that they are set for equal values for each blade, otherwise there will be a difference of pitch angle between the blades and the cylinder will cock on the piston and be subject to uneven wear in the bore. To check the setting of these stops the cylinder is first raised and then lowered to the limit of its travel in

each direction. In these positions the stop nuts must be adjusted to make even contact with the ends of all the bearing shafts. It should be noted, however, that the cumulation of tolerances may produce some discrepancy of angle in the counterweight marking, and a final check of the actual blade angle should therefore be carried out wherever possible. It is more important to obtain equal blade angles (by direct measurement) and equal bearing between counterweight bearing shafts and stop nuts than to obtain equal readings in the counterweights; these last are merely an index. Grease pressure applied through the greasing nipples will facilitate the movement of the blades for these checks.

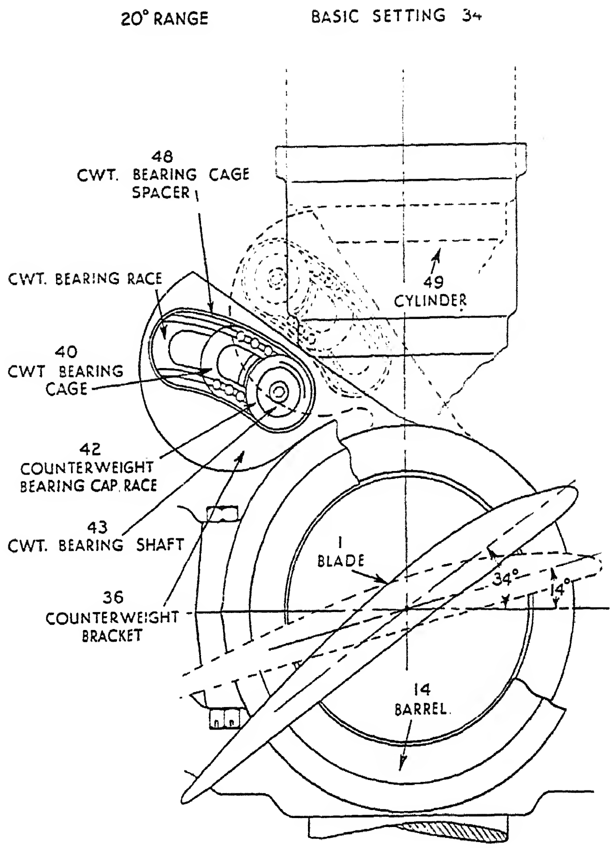


Fig. 6.—OPERATION OF CYLINDER AND COUNTERWEIGHT BRACKET TO EFFECT PITCH CHANGE

In direct-drive engines a change of 1° in the pitch setting is approximately equivalent to 70 r.p.m. on the ground, or to 100 r.p.m. in full-throttle level flight. For geared engines these differences in engine r.p.m. are usually greater in inverse proportion to the reduction gear ratio.

INSTALLATION OF AIRSCREW

The installation procedure is similar for all de Havilland Controllable Pitch Airscrews, except that in the 20° type it is necessary to release the spring draw bolt and remove both cylinder and piston heads to insert the spanner by which the piston is screwed on to the airscrew shaft.

Additional care is required, in the case of airscrews using the parallel spline, because the clearance is so very small that, unless the airscrew

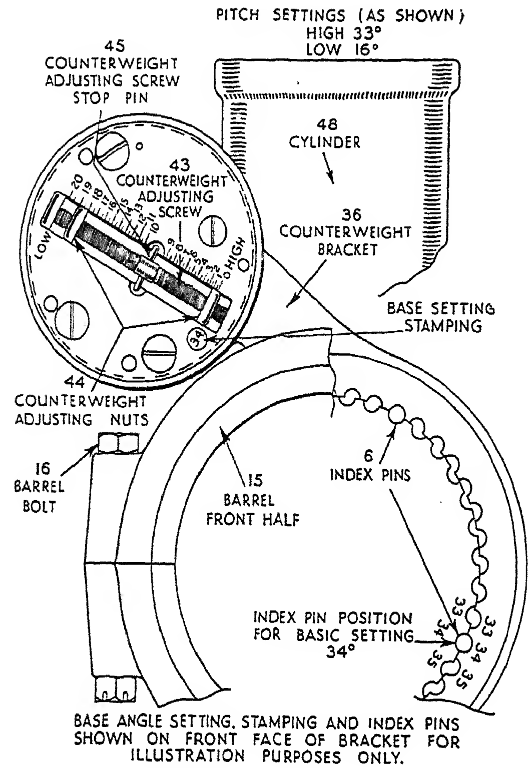


Fig. 7.—Sketch of counterweight bracket showing blade-angle adjustment

is accurately lined up with the airscrew shaft, it will not engage, and damage to the splines may easily result if force is used. Once engaged, the parallel splined airscrew should push smoothly into place. Should, however, the airscrew bind on the splines, it must not be driven home, but should be removed, and the cause of the interference ascertained before it is again offered up to the airscrew shaft.

Instructions for Installing Airscrew on Engine Airscrew shaft.

(1) Remove dust plug from airscrew shaft and ensure that the shaft is clear inside.

(2) For engines not employing the taper spline, place the rear cone on the engine shaft and press it back against the thrust nut or spacer.

(3) Remove the spring draw-bolt nut lock wire, spring draw-bolt nut and joint washer, the cylinder-head lock wire, and cylinder head in that order, using the special spanner provided to manipulate these components. Remove the sixteen head-securing screws, and lift off the piston head, together with the spring draw-bolt packing washer, taking care not to disturb the piston leathers. Withdraw the spring draw bolt, bucket, and the two spiral springs from the piston.

(4) Coat the airscrew hub splines and the airscrew shaft splines and threads with Whitemore's anti-seizing compound, graphite grease, or other preparation approved by the engine manufacturers, and smear the threads with a little clear grease.

(5) Mount the airscrew on the engine shaft, taking care that the piston and the airscrew shaft threads are in perfect alignment. In no circumstances should force be used to start this thread, for if there is binding or other indication that the thread is not properly started, serious damage may result.

(6) Tighten the piston, using the spanner provided. On the 5,000-

size airscrew, the torque required to tighten the piston nut is in the region of 850 lb./ft., and it is desirable, especially when first fitting the airscrew to the engine shaft, to approximate this loading by adding tube extensions to the tommy-bar provided and hanging a dead weight or exerting a pull and push at the requisite radius from the centre of the shaft. Whilst under this loading, the tommy-bar should be given one or two smart blows with a lead hammer near the box spanner.

Subsequently, after the first test flight, and at the first specified inspection period, the airscrew must be checked for tightness on the engine shaft by delivering a few smart blows near the box spanner whilst exerting a considerable pull on the end of the tommy-bar. Prior to making this check, care must be taken to remove the split pins securing the piston locking ring.

It should be noted that it is an essential condition, in putting up the piston, that the bar be hammered whilst the specified turning moment is being exerted on the box spanner. In no circumstances should the tommy-bar be loosely assembled with the box spanner and then hammered at its extremity.

The airscrew should not be installed or checked for tightness on the engine shaft whilst the engine is still hot, and particular care should be taken, when installing the airscrew, to see that the front-cone packing washer does not bind and that it pulls properly into place. The chance that this washer will jamb in the threads will be reduced if the inside diameter is pared until it passes freely over the threads. It should not be refitted after it has become soft and pliable, has lost its shape, or no longer fills the space between the flange of the piston and the front cone.

(7) Fit the lock ring to secure the piston, inserting $\frac{3}{32}$ in. steel split pins (two or three as required) through the lock ring and spider lip.

(8) Reassemble the piston head, tighten down and lock the sixteen piston-head securing screws. Great care must be taken to tighten down the piston-head screws evenly in order to prevent leakage at, or damage to, the piston leathers. It is recommended that all screws be first assembled and put down lightly, and thereafter that they be tightened down progressively across diameters as near as possible 90° removed. To ensure that the piston head is square to the piston, four holes are drilled through the piston head to register with the spigot of the piston underneath, and a careful check of the depth of these holes will indicate the amount and direction of any cant of the piston head. (Opportunity should be taken to check the piston-head securing screws for tightness at regular intervals.)

(9) Replace the spring draw-bolt packing washer, then mount the cylinder head, spring draw-bolt nut joint washer, and the spring draw-bolt nut. Screw up the draw-bolt nut by hand as far as possible without forcing, and then draw forward the whole assembly until it can be seen behind the cylinder head whether the hexagonal location on the spring draw bolt

has entered the cylinder head. If necessary, rotate the cylinder head anti-clockwise until it drops over the location, when the draw-bolt nut will screw down several turns further.

The cylinder head is then screwed into the cylinder, tightened down firmly upon the cylinder joint ring, and secured by means of the cylinder-head lock wire.

Finally, the draw-bolt nut is screwed hard down upon its joint washer, and in turn, locked to the flange on the cylinder head.

Constant-speed Unit

All de Havilland airscrews are essentially constant-speed airscrews, and where they have been fitted for two-pitch operation they can be converted to constant-speed operation by making provision for mounting the constant-speed unit and adding the pilot's control.

In some few instances it may be desirable to provide a slightly increased pitch range in the airscrew to derive the maximum advantage from constant-speed operation, and where the range of speed is considerably increased it may be desirable to exchange the counterweight caps, but in many cases no alteration to the airscrew will be required.

The control unit for constant-speed operation is simple and robust in design and consists of a small gear-type boost pump fed from the engine main oil supply, which delivers oil under pressure to the airscrew through the airscrew shaft.

In the unit with the boost pump is a spring-loaded governor which is driven from the crankshaft through gearing and actuates a small piston valve—which controls the flow of oil to and from the airscrew cylinder—admitting oil when the speed falls and so reducing the pitch of the blades and vice versa.

Mounting

To provide some latitude in mounting the unit, the base can be produced in alternative designs to meet special requirements, but otherwise it is standard and interchangeable, and only one type and size is manufactured.

As normally fitted, the unit is bolted and jointed to a mounting pad on the engine casing, in which are provided oil supply and drain passages, and also the means of drive.

The governor spindle is required to turn in fixed ratio to the crankshaft, and is therefore driven through a splined coupling, which may be specially provided, or may already exist on the engine as an auxiliary drive and be adapted for the purpose of driving the constant-speed unit.

These mounting arrangements permit the unit to be removed and exchanged easily when necessary.

The governing mechanism is mounted upon an extension of the

spindle which drives the boost pump, and the two governor weights, which are "L" shaped and pivoted at the angle, are arranged inside a metal cup surrounding the spring.

The piston-type control valve slides in the bore of the hollow spindle, in which are provided ports communicating with the high-pressure oil supply and with the actuating cylinder of the airscrew.

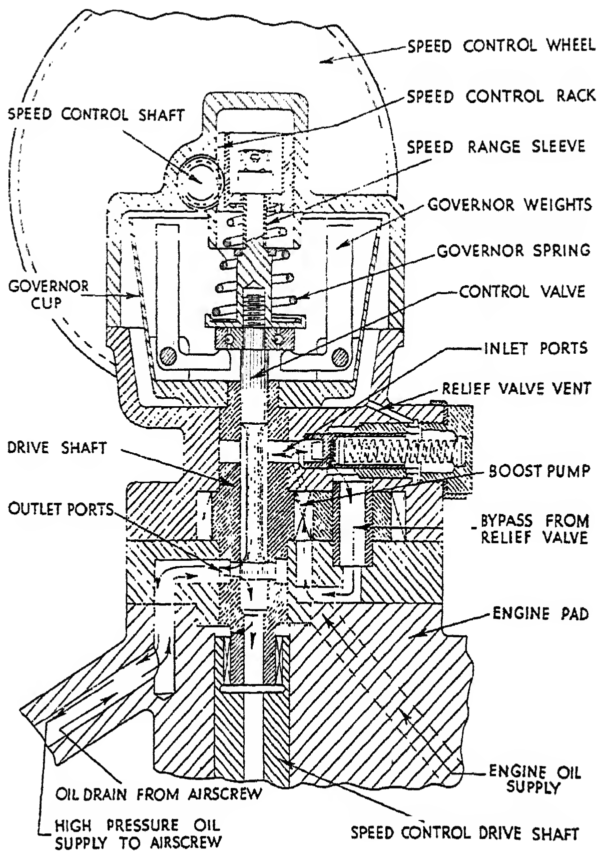


Fig. 8.—Constant-speed governor in section

The shaft, boost-pump gears, and governor weight assembly revolve as one unit; whilst the control valve, the governor spring, and the plunger for pre-loading the governor spring have only a reciprocating motion.

On the upper end of the control valve a small journal ball bearing is mounted, whose centre race remains stationary and takes the thrust of the governor spring, whilst the outer race rotates with the governor weights and takes the lift or thrust which results from the tendency of the governor weights to move outwards under centrifugal force.

It will be noted that centrifugal force is always acting against the spring, and will, for any variation of speed, achieve a balance either by compressing or permitting elongation of the spring, thus moving the control valve in one direction or the other.

The waisted section of the control valve is surrounded by oil at a pressure of about 200 lb. per square inch, and immediately reduction in speed occurs, the control valve falls, due to the action of the governor spring, a port in the spindle bore is uncovered, and oil is passed via an annular collecting chamber into the airscrew operating cylinder, thus

forcing the blades into fine pitch as far as may be required to restore the speed to the controlled value.

Conversely, if the speed rises, the control valve is lifted and the oil drain opened, permitting the airscrew counterweights to move the blades towards coarse pitch until decreasing revolutions return the piston valve to the neutral position and prevent further escape of oil from the cylinder.

To alter the speed, therefore, it is only necessary to adjust the load on the governor spring, so displacing the control valve, which will allow a flow of oil to or from the airscrew operating cylinder and permit the airscrew blades to move until the change in r.p.m. at the governor is sufficient to restore the control valve to the neutral position.

In flight there is continual movement of the governor and control valve, since many factors tend to vary the speed of the airscrew, and satisfactory operation of the entire system can be obtained only when the sensitivity of the governing unit is at maximum. In this way only is it possible to correct for small changes in speed quickly enough to maintain the speed within close limits of the desired value. The sensitivity is dependent upon the proper selection of the restoring force, and also upon the magnitude of the force, due to friction and other mechanical causes, opposing the movement of the control valve and hence of the governor weights.

Hunting

In the fundamental design of governors, one of the most important considerations is so-called "hunting," and it is essential that hunting tendencies be eliminated from any design before even an approximation to satisfactory operation can be obtained.

Hunting may be defined as a condition of operation characterised by a continuous uniform periodic variation in the speed of the governed unit above and below the speed which the governing unit is set to control.

Characteristics of the Governor

The characteristics of the governor which determine whether or not it will hunt are its *stability*, *sensitivity*, and *response*.

Stability is that characteristic of any system of forces initially in equilibrium which will tend to maintain that state in such a manner that, when the equilibrium is disturbed, forces will be set up which will cause the system to return to its original condition of balance.

The *sensitivity* of the system is measured by the magnitude of the force required to disturb the equilibrium of the system to such an extent that restoring forces are set up.

The *response* of the system is measured by the time required for the system to return to the state of equilibrium after the restoring forces have been set up, which is determined by the magnitude of the restoring forces.

When the governor assembly is rotating at any selected governing

speed, the control valve is held in equilibrium because the centrifugal force due to rotation of the governor weights is opposed by the force due to compression of the control spring.

For stability the spring characteristics must be such that at any given speed the force exerted by the spring must be greater than the centrifugal force exerted by the flyweights when they are displaced outward from the axis of rotation, and the force exerted by the spring must be less than the centrifugal force exerted by the flyweights when they are displaced inwards towards the axis of rotation. If this requirement does not exist, the unit will not return to the neutral position after a deviation from the set speed has caused a displacement of the flyweights. The difference between the force exerted by the spring and the centrifugal force of the flyweights is called the *restoring force.*

The restoring force must be chosen so that, as the speed of the governor unit is returning to the set value after a disturbance, the force is great enough to overcome friction in the system and return the governor weights to the neutral position.

The Restoring Force

The restoring force at a given deflection must not be too great, however, as the *sensitivity* of the system will then be affected adversely, because the movement of the flyweights for a given change in speed will be very small and the spring force required to balance the increased centrifugal force will be obtained at a very small spring deflection. This implies a correspondingly small movement of the control valve and hence a sluggish flow of oil through the small port openings, with consequent poor response of the governed unit.

Initial Experiments

A considerable amount of experimental work was necessary to determine the magnitude of the restoring force which would give completely satisfactory operation of the governor. These initial experiments were carried out with a cylindrical-helical spring, and it was found that satisfactory governing could only be obtained over a very small speed range, i.e. at speeds when the restoring forces were satisfactory.

The variation in the magnitude of the restoring forces at different set governing speeds is due to the fact that the centrifugal force of the flyweights varies as the square of the r.p.m., and therefore the centrifugal-force curve plotted against r.p.m. has a constantly varying slope.

This implies that the change in centrifugal force due to a given displacement of the flyweights from the neutral position has also a constantly varying value throughout the governing speed range.

The force curve of a cylindrical-helical spring, on the other hand, plotted against deflection, has a constant slope. Consequently, the change in spring force due to a given displacement of the flyweights from

the neutral position has a constant value throughout the governing speed range.

Hence the restoring force, which is the difference between the change in centrifugal force and the change in spring force, has a constantly varying value throughout the governing speed range, when a cylindrical-helical spring is used.

Satisfactory operation can therefore only be obtained over a very small speed range with this type of spring.

This difficulty is overcome by fitting a conical-helical spring, since this type can be designed so that the change in spring force due to a given displacement of the flyweights from the neutral position has a constantly varying value throughout the governing speed range, and the characteristics of the spring are chosen so that the restoring force is satisfactory over the entire governing speed range.

Hunting tendencies are eliminated by a proper selection, based on extensive experimental work, of governor characteristics, i.e. *stability*, *sensitivity* and *response*, and by reducing the frictional drag and the inertia of the moving parts to a minimum. The inertia of the system is minimised by the compact design and light weight of the parts comprising the governing mechanism, whilst the frictional drag opposing the movement of the control valve is reduced to a minimum by combining the sliding movement of the valve with a rotary motion. This movement has been readily accomplished by locating the control valve within the drive shaft, so that the valve itself does not rotate.

Since the valve is hydraulic, friction is reduced further, as the valve is always working in a bath of oil.

The Control Valve

The control valve is designed so that it does not carry any load due to the pressure of the oil. The necessity for any force other than that required for overcoming friction in moving the valve is thus eliminated. This end is accomplished by the " Balanced-valve " construction, where loads due to fluid pressure do not cause movement of the valve, whilst it will be appreciated that this design of valve permits the use of small clearances to minimise leakage without excessive friction and without danger of seizing.

In the absence of any provision for relative motion between the valve and its housing, especially when the working clearance is small, the valve tends to stick, and additional force is required to shear the oil film before the valve can move. This reduces the sensitivity of the governor.

Immediately the oil film resistance has broken down, however, the accumulated force produces a relatively large movement of the valve, causing it to overshoot the position corresponding to correct governor control.

A similar lag in valve movement occurs when the valve is being

returned to the equilibrium position by the restoring force, and this causes the valve to overshoot the neutral position, resulting in surging or "hunting" of the governor.

By introducing relative movement between the valve and its housing, however, the oil film resistance is practically negligible and the slightest change in axial force acting on the valve produces an immediate and proportional movement of the valve itself, so providing a control of great sensitivity which is, for all practical purposes, dead-beat.

The Flyweights

The flyweights are enclosed in a cup so that any oil which escapes into the housing will not interfere with their operation. This construction ensures that any oil which is caught in the cup will rotate with the flyweights, and thus the possibility of the friction on the flyweight bearings due to side loads imposed on the flyweights by their being dragged through the oil with consequent decrease in sensitivity is

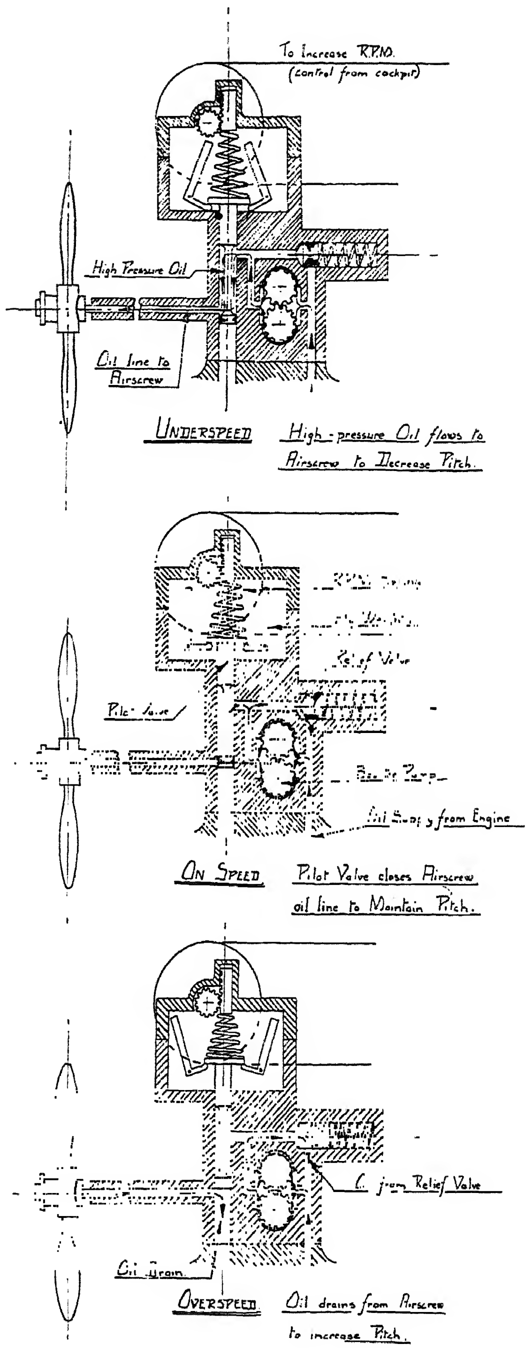


Fig. 9.—DIAGRAMMATIC C.S. UNITS—UNDERSPEED, SPEED, OVERSPEED

eliminated. This feature is particularly important when the governor unit is mounted on the engine at an angle or vertically downwards, in which position the flyweight assembly is naturally submerged in oil, and in fact it enables the governor unit to be fitted in any position without detriment to the governing action.

Operation of the Governor Unit

The operation of the unit will be clear from Fig. 9, showing the conditions of "underspeed," "overspeed," and "onspeed," where, in the first case, oil is being forced into the airscrew to reduce the pitch and increase the revolutions ; in the second case, it is being released from the cylinder to drain, enabling the airscrew counterweights to increase the pitch of the blades, so decreasing the r.p.m. ; whilst in the third case, the airscrew is on speed and the port is closed, and just sufficient oil is trapped in the airscrew operating cylinder to maintain the pitch setting necessary for the chosen r.p.m.

In this last condition the counterweights are holding the blades hard up to the oil imprisoned in the cylinder, and no further movement can occur ; meanwhile, the whole volume of oil delivered by the pump is circulating through the specially designed relief valve.

It will be apparent that little oil is required by the unit in normal operation, as the movements of the cylinder, though continuous, are small in amplitude, and the oil required to make up leakage is also small.

In order to secure a quick response to the governor control, however, the boost pump has been given a capacity of $2\frac{1}{2}$ gallons per minute at a speed of 1,750 r.p.m., which is ample to operate airscrews much larger than any in production at the present time.

Airscrew Adjustments and Flight Tests

In general, it can be accepted that the performance of the aircraft determines the pitch range required in the airscrew, and whereas the 10° airscrew is usually adequate for the commercial type of aircraft, it is necessary to provide a 20° pitch range for many types of high-performance, supercharged aeroplanes in order to secure, on the one hand, full take-off r.p.m. on the ground, and on the other, to prevent excessive r.p.m. when flying at high speed at high altitude.

It is unnecessary and undesirable to employ a larger pitch range than is actually required, however, and in continuation of the policy to maintain a range of airscrews from which every probable requirement can be met, de Havilland have provided an intermediate basic type of 15° range.

The size, type, and settings required for each installation are determined within close limits on the data supplied by the aeroplane manufacturers, and any necessary readjustments of the airscrews are made on the flight test data of each prototype aeroplane.

It will not often be necessary, therefore, to alter settings in service,

but where, exceptionally, such alterations are required as the result of more extended flight trials, they can usually be effected in the counterweight adjustment without disturbing the basic setting.

If, however, it is necessary to re-index the airscrew, it should be borne in mind that the stop nuts in the counterweights are set to limit the blade angles to safe or desirable angles in both fine and positive coarse pitch positions, and that alterations, particularly on the fine-pitch side, should only be undertaken with the utmost caution.

Normally, the fine-pitch stop nuts are adjusted so that they will just permit maximum permissible revolutions at a specified boost whilst the aeroplane is stationary on the ground, whilst the coarse-pitch stop nuts are set to allow full cruising revolutions at critical altitude, which adjustment will usually allow the constant-speed control to function in certain conditions of power descent.

Adjusting Screws and Stop Nuts

There is a growing tendency, however, to specify alternative settings to meet special requirements of take-off, climb, etc., in the engine, and also to provide a means of checking the sparking plugs by "magneto drop" under conditions of high r.p.m. and boost, and it is desirable therefore to consider further the function of the adjusting screws and stop nuts in a constant-speed airscrew.

In a steady take-off and climb to altitude, there is a progressive increase of blade angle, the movement accelerating fairly quickly until the aeroplane attains optimum climbing speed, and then more slowly as height is gained.

The bearing shafts of the airscrew are just touching the fine-pitch stop nuts at maximum r.p.m. whilst the aeroplane is at rest, but immediately it begins to roll, the bearing shafts move away from the nuts as the blade angles begin to increase.

In steady climb the stop nuts place no restraint on the movement of the blades until, at about critical altitude, the bearing shafts have moved to the coarse-pitch end of their travel, where they are arrested by the coarse-pitch stop nuts.

In this simple case it will be apparent that the stop nuts have performed no useful function, and that such an airscrew could be flown up to a certain height without either adjusting screws or nuts in the counterweights, *as both airscrew and governor are set to give the same revolutions at take-off and at altitude.*

If, however, the fine-pitch stop nuts are set to restrict the movement of the blades towards fine-pitch, whilst the governor remains set at maximum revolutions and the boost at take-off value, the governor will be passing oil to the airscrew, which, notwithstanding, will be unable to move and will therefore hold the r.p.m. at something less than maximum permissible.

In this case *the governor is set for maximum permissible static r.p.m.*,

but the airscrew is adjusted for something less than maximum permissible r.p.m., and as the aeroplane begins to roll, the r.p.m. will increase, until at the value for which the governor is set, the sustained pressure is shut off from the airscrew and the counterweight bearing shafts are at liberty to move away from the stop nuts, thus permitting the airscrew to commence constant speeding.

This adjustment usually is made to permit the airscrew to turn at take-off r.p.m. with take-off boost at the moment of leaving the ground, but obviously it can be advanced or delayed, as may be necessary to comply with the requirements of the engine.

With such an adjustment, the airscrew is virtually in fixed pitch on the ground, and " magneto drop " may be checked on the r.p.m. indicator without difficulty.

Similarly, in cases where airscrew is giving maximum permissible r.p.m. at the chocks, it is only necessary to close the throttle until the airscrew drops about 50 r.p.m. in order to check magnetos and plugs.

Where the coarse-pitch stop nuts have been set for best performance at altitude, and it is desired to descend regularly at medium or moderate power, some form of automatic mixture control or fuel/air ratio indicator will be of great convenience, but where these adjuncts are not provided, the coarse-pitch stops should be set to a lower pitch, so that at cruising critical altitude, constant-speed operation requires practically all of the high pitch for cruising power in level flight.

This adjustment will permit shifting the airscrew to positive coarse-pitch for manual adjustment of the mixture control.

In many cases performance will not be impaired appreciably if an airscrew is used of slightly smaller pitch range than is required to permit full take-off r.p.m. static as well as constant r.p.m. in a power descent.

In such cases satisfactory performance may be obtained by indexing the airscrew so that the low-pitch limiting stop allows the engine to turn up to within 100 or 200 r.p.m. of the maximum permissible on the ground, whilst the coarse-pitch stop is set to a sufficiently high value to prevent engine overspeeding under conditions of reduced power descent.

Where 10° or 14° airscrews are in question, the full range can usually be employed, but if the full range is not needed, the stops can be adjusted to limit either or both pitch angles as described for the 20° airscrew.

In making any of the foregoing adjustments, it is much to be preferred that any unused portion of the pitch range should occur at the fine-pitch end of the brackets, and when the pitch settings have been finally decided, the airscrew should be re-indexed if necessary to bring the base setting to within 10° of the coarse-pitch setting.

Installation and Adjustment of Constant-speed Controls

The installation of the pilot's control to the constant-speed unit is a most important matter affecting the successful working of the engine

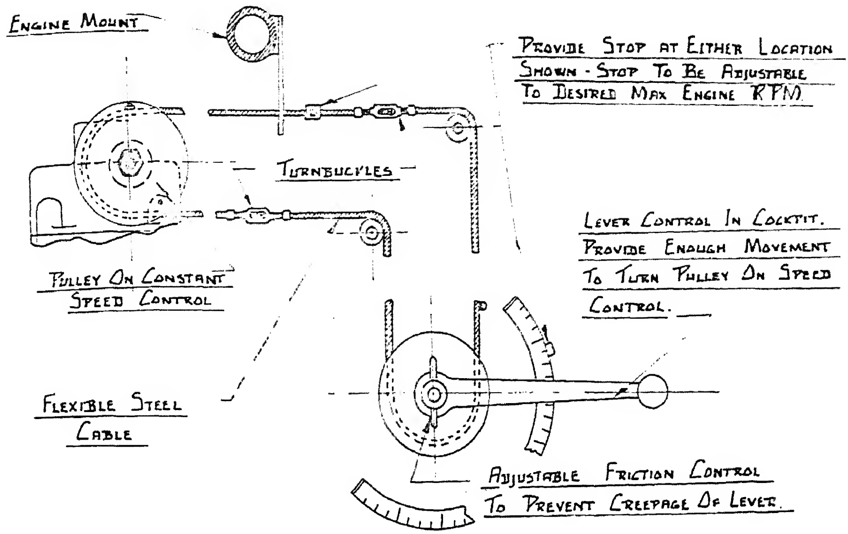


Fig. 10.—Typical flexible cable control lay-out

and airscrew in combination, and every endeavour must be made to ensure that the critical adjustment of which the unit is capable is not destroyed by inefficiency of the means provided to operate it.

This control is at least as important as the throttle control in all cases, but in multiple-engine installations it is necessary that the pilot be enabled to synchronise his engines quickly and conveniently, and this calls for the utmost precision of movement between the actuating lever and its follower.

The planning of a satisfactory system of controls requires considerable care and skill, and experience to date has demonstrated unmistakably that, whilst certain systems have features which fit them for one type of installation, there are at present none which can be recommended as being equally suitable for all installations.

It is most desirable, therefore, that the question of design and layout of the pilot's control for constant speed airscrews should be taken in hand as early as possible, and resolved along lines in keeping with the following requirements :

(1) Lost Motion

There must be no lost motion arising from slackness of cables, differential expansion, weaving or distortion of wings in flight, working clearances in the push-pull type of control, angular displacement of bell-crank levers, slackness of pin joints, stiffness of cable laid around pulleys or in fairleads, stretch of cables, lack of rigidity at anchorage points, etc., etc.

Furthermore, all such controls should be laid in conduits or otherwise protected against accidental fouling.

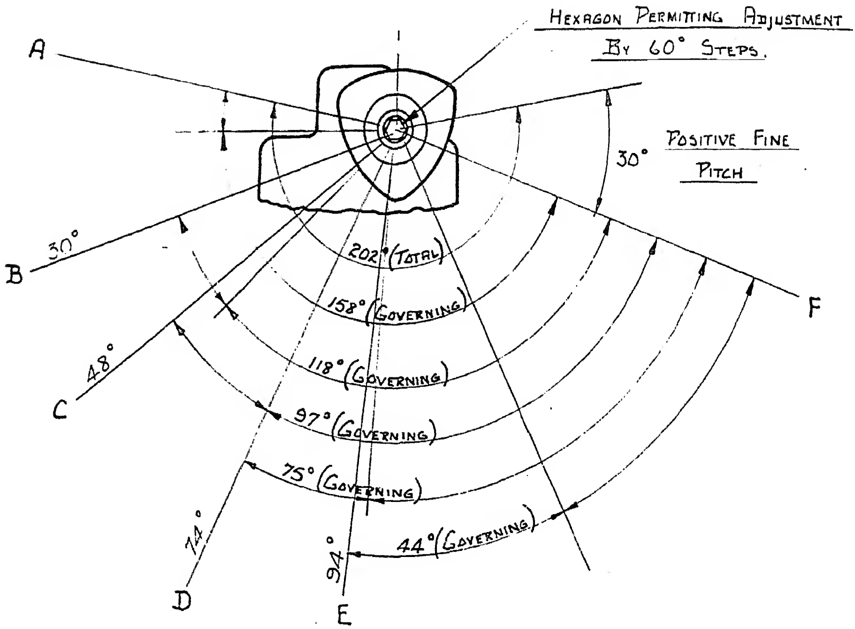


Fig. 11.—ADJUSTMENT OF GOVERNING SPEED RANGE AND POSITIVE PITCH POSITIONS AT GOVERNOR ACTUATING SPINDLE

(2) Creep

The controls must be held against creep, but should be smooth and easy to handle and capable of minute adjustment. As an index to the possibilities of this control, it requires in the average installation a movement on the control unit plunger of only ·001 in. (one-thousandth inch) to vary the speed by 4 r.p.m.

Within this specification, electrical, hydraulic, and mechanical controls have been devised and produced in such numbers and combinations that it is beyond the scope of this article to deal with them in detail.

Principles of Adjustment

The broad principles of adjustment, however, are independent of the detail arrangements of the control lay-out, and the simplest type has therefore been chosen to illustrate the procedure.

The actuating spindle of the governor unit in the basic type is provided with 202° of angular movement, which includes positive coarse pitch, a governing range of 1,000 to 2,800 r.p.m. at the governor drive shaft and positive low pitch.

In many engines the crankshaft speed falls within these limits at all useful powers, and it is possible to run the governor at crankshaft speed, but when the range is keyed higher than this, it is necessary to gear the drive accordingly to provide a speed of about 2,520 r.p.m. at the governor spindle whilst the engine is turning at its maximum rated speed.

About 30° of this movement represents positive fine-pitch, which, as has been explained, is very rarely required, and never in its entirety, but even so, the range of movement for the full governing range and positive coarse-pitch is still 172°—a most inconvenient angle through which to operate the pilot's control.

The difficulty cannot be solved satisfactorily by "gearing up" the control, because the sensitivity is geared down in proportion, but as few installations require control over the full range of 1,800 r.p.m., opportunity is taken to reduce the range of the governor by fitting one of a series of adjusting sleeves.

In the positive coarse-pitch position, if no sleeve is fitted, the rack will engage the nuts at the top of the piston valve and lift it positively to open the port and release the oil from the airscrew cylinder.

The airscrew will therefore remain in positive coarse pitch until the rack has lowered the valve to the position where it exactly covers the port, but immediately it moves lower than this, oil will be admitted to the airscrew cylinder and the airscrew will commence to constant speed at about 1,000 r.p.m. Continuing the movement of the rack, the governor spring will be compressed, but further movement of the valve will be arrested by the increase of speed and centrifugal force of the counterweights, and the valve will remain, reciprocating through a small travel, over the port.

Further compression of the spring will be balanced by a corresponding increase of speed until, at the end of the range, the underside of the plunger makes contact with a shoulder on the valve, which is then positively depressed to admit oil to the airscrew, which thereupon goes into the positive fine-pitch position.

The governing range therefore occurs between the points where the valve first registers over the port, and where it is positively depressed by the plunger, and if these points are brought closer together, the governing range will be reduced.

This adjustment is effected by fitting sleeves of varying lengths over the extension of the piston valve and adding packing sleeves of a larger diameter to make up a standard length, so putting the control spring under an initial compression, and raising the r.p.m. at which speed control begins.

The point at which the piston valve is depressed and positively fine pitch occurs does not change, and in effect the angular movement through positive coarse-pitch is increased by the same amount the control range is decreased, but as only a fraction of this positive coarse-pitch travel is required, the net result is a considerable reduction in the total angle of operation.

In most installations, it is possible by this means to reduce the travel of the pilot's control levers to a convenient amount without sacrificing any useful proportion of the constant-speed range.

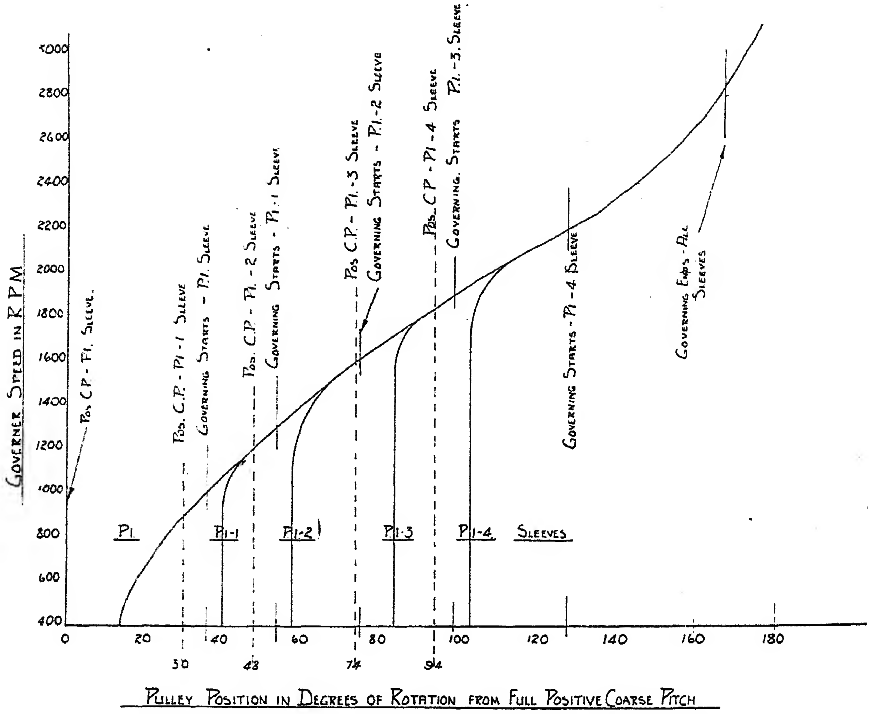


Fig. 12.—CURVES OF PULLEY POSITION AND GOVERNOR SPEED. (SLEEVE SIZES.)

Selecting Size of Sleeve

The size of sleeve is selected from the graph (Fig. 12) to suit the governing range required, which is usually that between maximum permissible take-off and something less than cruising r.p.m., but as all governors control up to 2,800, it is only the lower limit of the range which is important.

If, for instance, it is required to control from 1,600 r.p.m. upwards, sleeve Pl-2 is indicated, which is in full positive coarse-pitch at an angle of 48° from the basic reference line, commences to control at 58° and a speed of 1,200 r.p.m. and is in full control at 75° and 1,600 r.p.m.

Referring to the diagram on page 80, it will be apparent that, with this sleeve, the control spindle must be given an angular movement of from C to F or 124°, to include positive coarse-pitch and the required control range.

In the most simple type of installation the constant-speed unit is operated by a flexible cable passing over pulleys of equal size—one on the operating spindle and the other fixed to the pilot's control lever—on which it is secured to prevent creep—and the cockpit lever has therefore the same angular travel as its follower on the unit.

In this type of control it is not desirable to make adjustments by

releasing the clamps on the pulleys, as the cable is usually kinked at these points, and if released and readjusted, the kinks will tend to straighten out in the course of time and result in the control falling out of adjustment.

A better arrangement is to insert two turnbuckles in the control cable on which to make final adjustments and to take up any stretch which may occur in the cable.

It is most convenient to start with the assumption that the engine will be required to give maximum permissible revolutions on the ground, static, and to make any special adjustments afterwards, for which reason the airscrew stop nuts will be adjusted to permit full take-off r.p.m. at "take-off" boost.

Assembling Cables and Pulleys

The cables and pulleys of the pilot's control are next loosely assembled and tried to find the relative positions of the pulleys and clamping bolts, and to ensure that the required angle of movement can be obtained, for which purpose two radial lines are marked on the side of the governor pulley to represent the lines A and C, which include an angle of 48°.

As these marks are to be used to synchronise the pilot's control lever and the governor, they should be set off by protractor, and a piece of wire, twisted around some convenient standing part, will serve as a pointer to mark the angular movement of the pulley.

The control cable is then slacked off or disconnected, and the pulley turned as far as possible in the *opposite* direction to that in which the resistance of the governor loading spring is felt. The pulley is then in the basic positive coarse-pitch position, which is marked by fixing the pointer against the lower of the two lines.

If, then, the pulley is turned until the other line is opposite the pointer, it will have moved through an angle of 48°, and the governor will be in the full positive coarse-pitch position (as determined by the sleeve Pl-2). It may then be connected up to the cockpit lever, which must also be in the full positive coarse-pitch position.

Should any difficulty occur in obtaining synchronisation, provision is made for easy adjustment by fitting the pulley on a hexagonal location on the governor control shaft, thereby providing for six alternative positions.

The engine may then be started and run until it is warmed through, when with the constant-speed lever fully forward in the high-speed position, the throttle is opened until the engine is turning at maximum permissible revolutions.

Leaving the throttle in this position, the constant-speed lever is drawn slowly back until the revolutions just begin to drop, which, if the airscrew is correctly adjusted, should occur at or about the specified take-off boost pressure.

Immediately a perceptible drop in r.p.m. occurs, the throttle should be

closed without moving the constant-speed lever, and the engine switched off.

The first tendency of the revolutions to drop marks the end of the governing range, and if this occurs immediately, the constant-speed lever is moved, and at specified boost, no further adjustment of controls, governor, or airscrew is needed, for both governor and airscrew are set *and stopped* for maximum permissible revolutions which cannot then be exceeded in normal flight.

If, however, the constant-speed control lever moves some distance from the extreme high-speed position before any drop in r.p.m. occurs, it is an indication that the airscrew is in positive fine pitch, and that the revolutions are being held at maximum permissible by the angle of the blades.

With such a setting and with the constant-speed lever right forward, revolutions would begin to increase above maximum as soon as the aeroplane began to move, and it is desirable that either the control be readjusted to give maximum revolutions with the control lever right forward, or that some form of stop be fitted to prevent the lever being moved past the point at which this speed occurs.

A third case may arise in which, with both throttle and constant-speed control right forward, specified boost is obtained, but revolutions are below the desired value, and fall still further immediately the throttle is moved backward.

In this instance the airscrew is probably set for a lower speed than the governor, and the pitch must be decreased until maximum r.p.m. is obtained *or until further reduction of pitch produces no* corresponding increase of r.p.m.

This last condition would be an indication that the governor was stopped at too low a speed and required control adjustment to increase speed.

The means by which these and similar adjustments are made vary in the different types of actuating systems, and where they do not lend themselves conveniently to alterations of length or angular advance and retard in the connecting linkage, some form of fine adjustment is generally provided at the points of attachment to the pilot's speed-control lever or to the governor.

THE HYDROMATIC AIRSCREW

The construction of the hydromatic airscrew is similar to the counterweight type, in so far as a spider, barrel, barrel packing blocks, blades, blade bushings, and thrust races have been provided to perform the same functions as in the earlier design.

It has, however, a separate pitch-change mechanism of new design, which has the further advantage of being interchangeable between air-

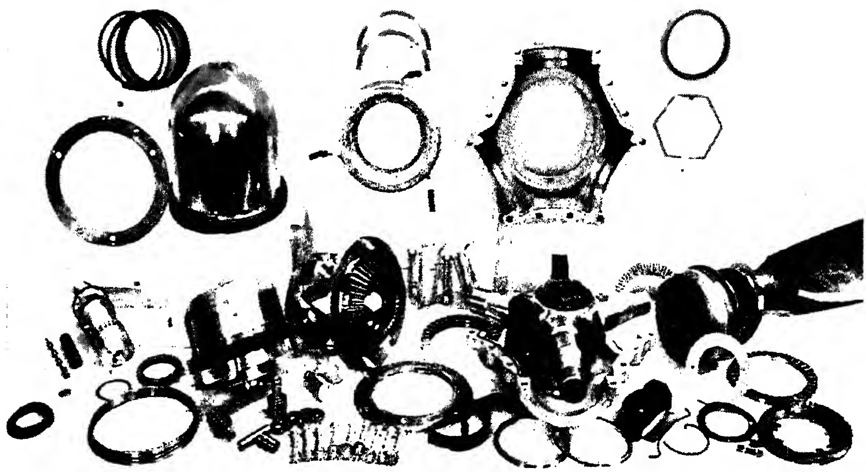


Fig. 13.—Components of the Hydromatic Airscrew which, it will be noticed, retains the blade screwing principles of the counterweight type De Havilland airscrew

screws as a separate assembly. This is known as the dome assembly, which also functions as a spinner.

As in the counterweight airscrew, the spider and barrel are finished from high-tensile steel forgings, the spider taking only thrust and torque loads, whilst the centrifugal loads are taken by the barrel. The blades are similar as to mounting and material to the standard type, but are provided with a collar of moulded plastic material between the inner roller bearing race and the radius at the blade root.

This plastic material furnishes a better seating for the race, protects the blade root from chafing, and gives a better stress distribution with a correspondingly increased resistance to fatigue.

Furthermore, the introduction of the plastic collar permits the use of an effective gland or oil seal between the barrel and the blade. Such an arrangement could not be used in direct contact with the blade, because it might lead to grooving of the blade shank and stress concentration.

By so closing the aperture around the blade shank it is now possible to maintain oil pressure on all the moving parts within the hub, with the result that all lubrication problems are eliminated and the wear and tear of components is reduced to minute proportions.

The Dome Assembly

The dome assembly comprises all the mechanism through which the pressures of oil on the piston are transformed into blade-twisting efforts.

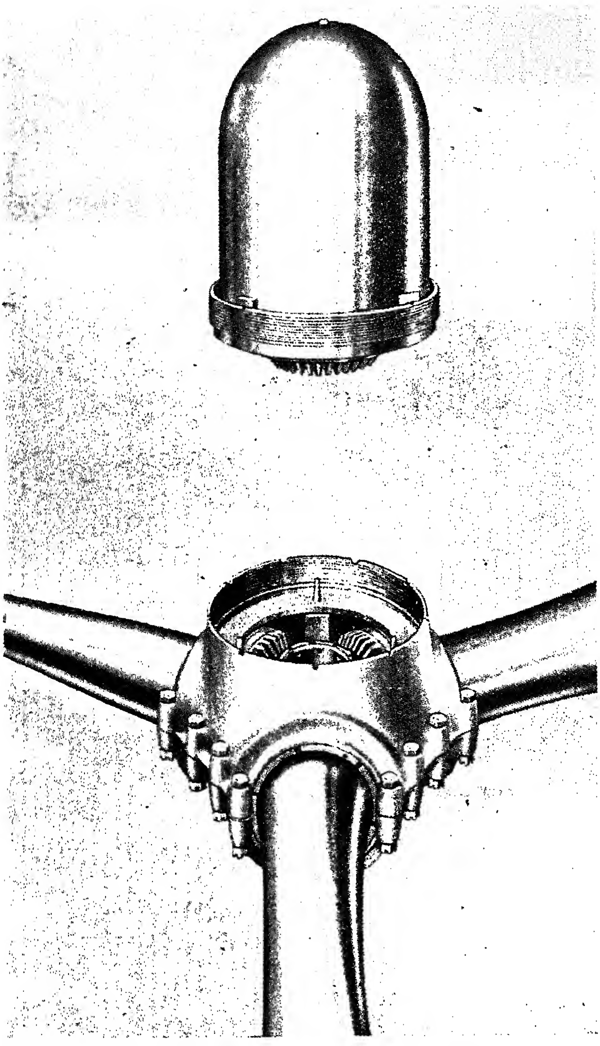


Fig. 14.—Hydromatic airscrew with dome removed

It consists of four major parts—two co-axial cylindrical cam members machined in high-tensile steel, a double-walled dome-shaped piston of aluminium alloy, and an external dome which is also of aluminium alloy, and functions as a cylinder whilst housing the whole assembly.

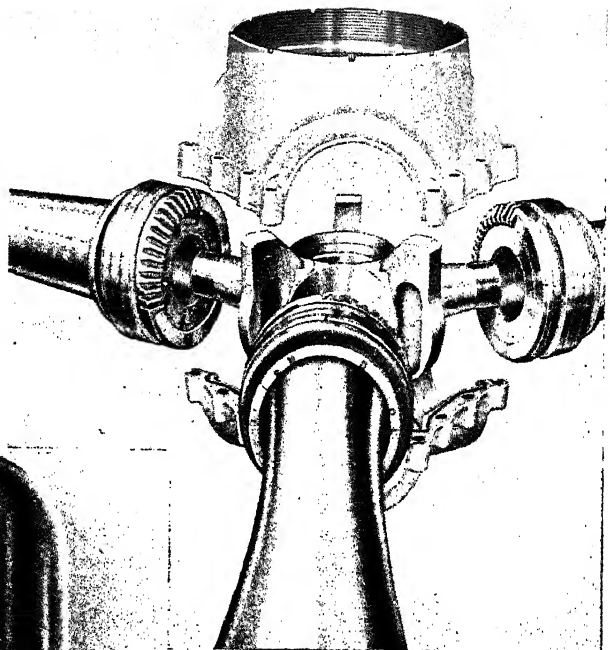
The outer or stationary cam member is fixed through a flange to the barrel and acts as a support for the other moving parts of the mechanism, and is the anchorage on which the thrust reaction of the cam rollers is taken.

The four cam tracks of this member are similar in form to the four tracks machined in the inner or moving cam member, except that the pitch slope is reversed, hence the rectilinear movement of a common roller in these tracks occasions an equal but opposite movement of each cam member. Since, however, the outer cam member is fixed, a double rotary movement of the inner member relative to the hub is obtained.

Both members are machined with lightening holes between the tracks to reduce weight, and the inner or moving member, with its integral bevel-drive gear, is supported at both ends by large-diameter ballraces spigot-mounted in the bore of the fixed member.

The piston, between whose outer and inner skirts four equally spaced

Fig. 15.—HYDROMATIC AIRSCREW WITH HUB AND BLADES DISMANTLED



cam rollers are carried, slides in the bore of the moving member and envelops the outer or fixed member. When it reciprocates, due to variations of oil pressure in the cylinder, a rotary movement of the bevel drive gear is produced, which is proportional to the length of stroke and to the slope of the cam track.

For the constant-speed range of movement the cam slots are straight and steep, and the piston travel compared to the angular rotational movement of the inner member is high, but when the blade pitch has reached the maximum operating value, the cam rollers are about to enter the less steep part of the cam tracks, where the mechanical advantage of the piston is much less. The normal operating oil pressures are therefore unable to twist the blades any further against the forces tending to return them to fine pitch.

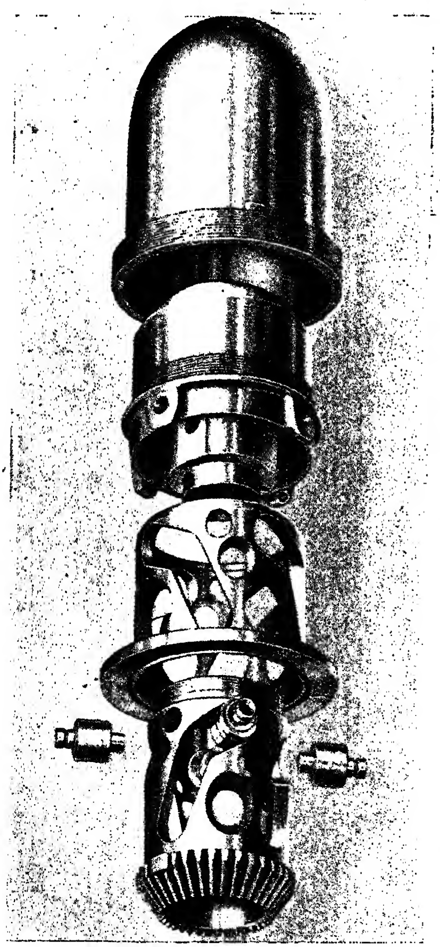


Fig. 16.—HYDROMATIC AIRSCREW. DOME ASSEMBLY COMPONENTS

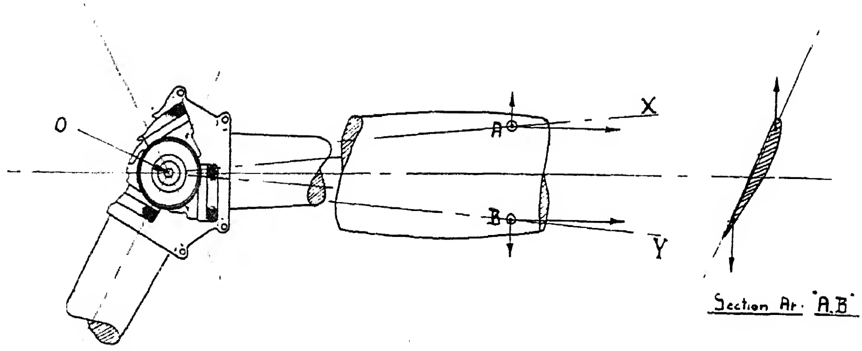


Fig. 17.—SKETCH OF FORCES TENDING TO TURN BLADE TOWARDS FINE PITCH

Thus a maximum or safe blade pitch-limiting stop is provided for constant-speed operation, and an independent supply of high-pressure oil requires to be brought into use to force the blades beyond this pitch, so that the airscrew cannot be " feathered " except by deliberate action on the part of the pilot.

Whereas in the counterweight type of airscrew the blades move into fine pitch under oil pressure and into coarse pitch automatically when the oil pressure is released, in the hydromatic type the operation is effected in both directions by oil pressure, although the natural tendency is always for the blades to move into fine pitch.

This tendency, which was also present in the counterweight type, is illustrated in the sketch (Fig. 17), where it is assumed that two unit masses A and B in a rotating blade are exercising individual pulls along the lines OAX and OBY passing through the axis of rotation, and that these pulls are split up into components at right angles.

The two larger components lying along the blade are taken as a pull at the blade root, and it will be clear that the sum of all such components at all points within the envelope of the blade is the total centrifugal pull felt at the roller races.

The smaller transverse components appear to balance out by stressing the material of the blade, but on referring to a section of the blade at this point, it will be seen that they form a couple which acts to turn the blade on its axis towards fine pitch.

This twisting movement actually attains a very considerable value in large airscrews, but in counterweight design it was always more than counterbalanced by the counterweights.

In the hydromatic airscrew, however, it is not counterbalanced, and acts together with engine oil pressure on the forward side of the piston,

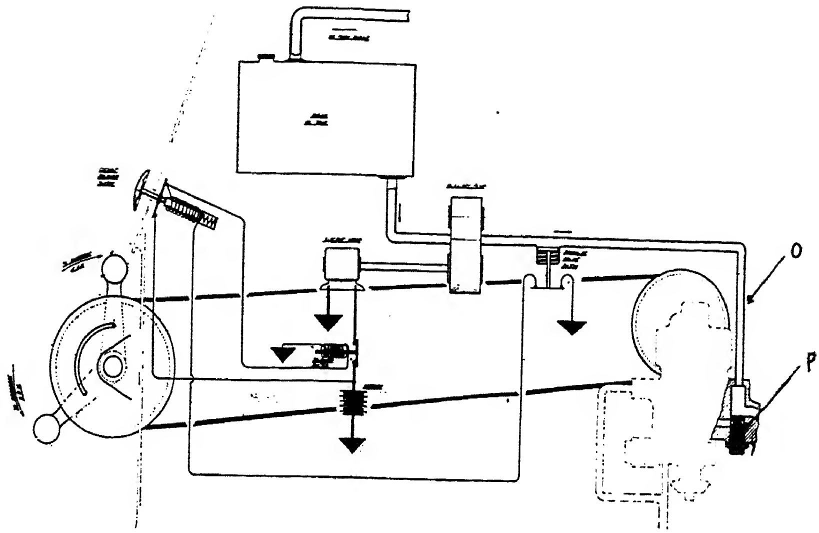


Fig. 18.—Diagrammatic arrangement of controls and independent oil supply for feathering and unfeathering hydromatic airscrews

against the higher pressure supplied by the governor on the rear side of the piston.

Besides permitting the use of a piston of sufficient size to envelop the cam members, this arrangement provides a dome and in most cases dispenses with a spinner, whilst the engine oil pressure, which acts with the blade reaction, produces a more resilient and constant load, and assists in smoothing out the variations of centrifugal and aerodynamic torque around the blade axis.

Feathering the Blades

When it is desired to feather the blades, an auxiliary pressure supply system is put into operation. A typical example of such a system is shown in Fig. 19. The pump is mounted between the engine oil tank and the constant-speed governor and supplies oil under pressure through line 0 to the cut-out valve built into the base of the governor. This auxiliary system allows the pump to draw its oil from the engine oil tank ; alternative installations employ either a separate oil tank or use fluid from the hydraulic system of the aeroplane in place of engine oil and a special pump.

The pump builds up pressure very rapidly in line, and this disconnects the governor from the airscrew and at the same time opens the pipe line to the airscrew by compressing the spring P in the cut-off valve. This feathering oil pressure is transmitted to the rotating airscrew shaft past the oil transfer rings C, through port E of the distributor valve assembly,

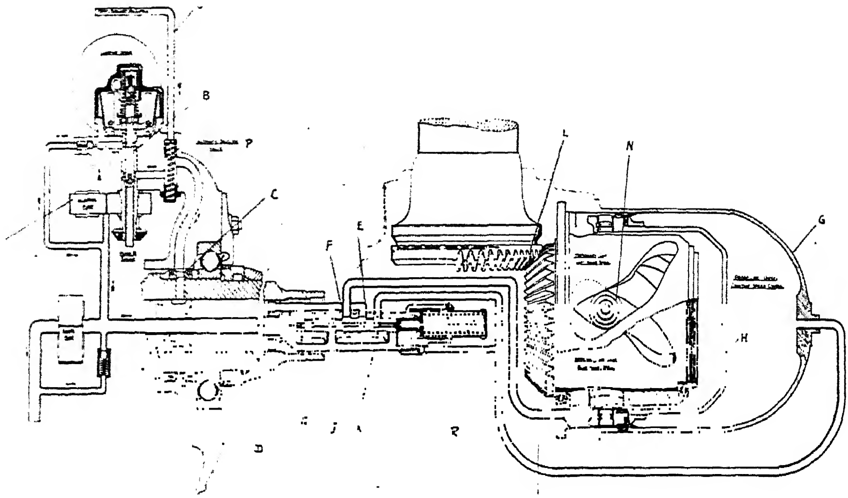


Fig. 19.—Diagrammatic arrangement—airscrew under constant speed control

out through port F to the inboard side of the piston H. The piston moves out under this pressure, and forces the engine oil on its outboard side in the dome G, through ports K and J, into the oil supply pipe D, and back into the engine lubricating system. As the piston moves out, the blades turn through an increasingly coarse angle until the motion is finally stopped by the rotating cam coming against an adjustable mechanical stop (not shown in the sketch) set for the fully feathered position of the

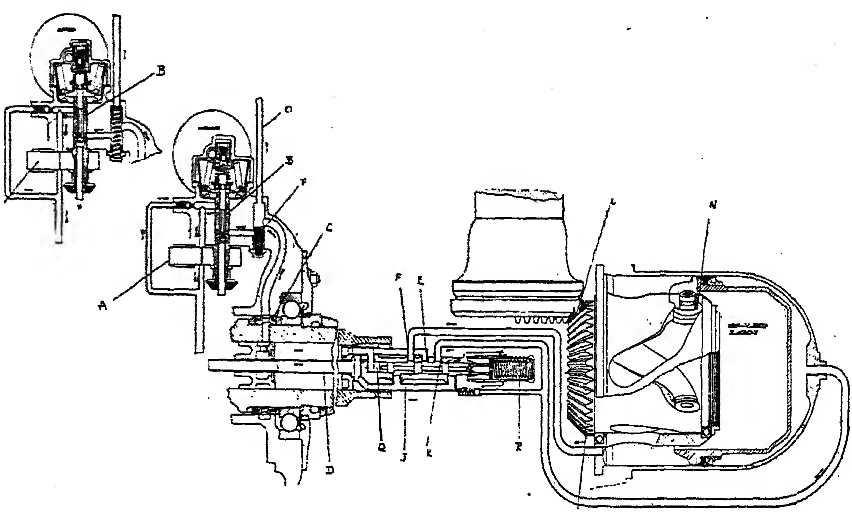


Fig. 20.—Diagrammatic arrangement—airscrew commencing to unfeather

particular blade design in use. With all motion stopped and the feathering pump still functioning, the feathering oil pressure builds up until it reaches 400 lb. per square inch, at which point a pressure cut-out switch opens the electrical circuit operating the pump by de-energising the solenoid holding the cockpit solenoid switch closed. With the blades feathered, engine rotation is stopped, and consequently the blade centrifugal twisting moment and engine oil pressure have dropped to zero, and the blades remain stationary in the feathered position. The entire feathering operation is accomplished in an average time of 9 seconds.

Unfeathering the Blades

To unfeather the blades, the pump is again started and permitted to build up a pressure greater than 400 lb. per square inch by holding the cockpit solenoid switch closed. At approximately 500 to 600 lb. per square-inch pressure, the load at Q at the base of the distributor valve in the airscrew is sufficient to force the distributor valve out, compressing spring R, and the valve moves towards the position shown in Fig. 20, thus disconnecting the engine oil system from the dome. The oil from the pump enters the dome on the outboard side of the piston through ports E and K as the distributor valve moves out, and this oil pushes the piston inwards to unfeather the blades. The oil on the inboard side of the piston is, of course, forced out through ports F and J into the engine.

The unfeathered airscrew in a moving aeroplane starts to windmill, and when the engine reaches a reasonable r.p.m., the cockpit solenoid switch is released by the pilot. Thereafter the airscrew continues to windmill, and it is thus possible to put the engine in operation again by switching on the ignition. The moment the feathering pump stops, the spring in the cut-out valve in the governor disconnects the feathering pump line from the airscrew and places the governor back into the system, and the airscrew runs again at the speed for which the governor is set by the cockpit control lever.

Oil Supply

The Hydromatic airscrew during normal constant speed operation requires two sources of oil supply, one from the constant speed governor and the other under normal pressure from the engine oil system. Referring to sketch (Fig. 19), oil from the constant-speed governor A is permitted to enter the hollow drive gear shaft B of the governor, and thence to the airscrew shaft, when the engine is turning faster than the speed for which the governor is set. Governor oil is thus metered at the top port of the drive gear shaft, and enters the rotating airscrew shaft by means of the oil transfer rings C. It then follows the path described above for the oil during the feathering operation, to the inboard side of the piston.

At the same time, oil from the engine lubricating system under normal engine oil pressure, entering the airscrew mechanism through the supply pipe D in the centre of the airscrew shaft, reaches the outboard side of the piston through ports J and K.

The governor oil pressure builds up until it exerts a force greater than the sum of the forces which oppose motion of the piston outward into the front of the dome. These forces are :

(1) Engine oil pressure multiplied by the effective piston area.

(2) The net blade twisting force consisting of the blade centrifugal twisting moment modified by the aerodynamic twisting moment.

(3) Friction of the moving parts of the airscrew mechanism.

The net blade twisting force is transmitted from the blade gear segment L to the rotating cam M, and through the cam rollers N acting in the slots of the rotating cam, to the piston.

The blade centrifugal twisting moment is a moment acting on the airscrew blade around its longitudinal axis in the direction of a decrease of blade angle. The aerodynamic twisting moment is usually opposite in direction to the blade centrifugal twisting moment, and depends on the position of the resultant centre of pressure of the airfoil section of the blade in front of the centre of rotation of the blade (the blade's longitudinal axis). In normal level flight this aerodynamic moment is relatively small in magnitude.

As the governor oil pressure builds up to a value on the piston just greater than the sum of these three forces, the piston starts to move out towards the front of the dome, and engine oil in front of the piston is displaced back into the engine lubricating system. This outward movement of the piston increases the pitch of the blades and slows down the speed of the engine to the r.p.m. for which the constant-speed control is set, the pilot valve in the governor descends to mid position, thus shutting off the top part of the drive-gear shaft and cutting off the supply of governor oil to the airscrew. The oil under pressure from the pump then circulates through the relief valve back to the engine, and the airscrew runs on speed.

Should the engine r.p.m. fall below the speed for which the governor is set, the pilot valve in the governor descends still further, opening the bottom of the drive-gear shaft to drain. Engine oil in the dome on the outboard side of the piston is always, during normal airscrew operation, under pressure from the engine oil pump. This pressure acts as if a spring were placed between the outer end of the piston and the front of the dome, the spring, however, having the unusual characteristic of exerting a constant force regardless of the amount of its compression. The centrifugal twisting moment of the blade, aided by this "spring" force, moves the piston inward, overcoming friction and forcing governor oil back through the governor to drain. As the pitch of the blades decreases, the engine speed picks up and the pilot valve in the governor is raised, closing the

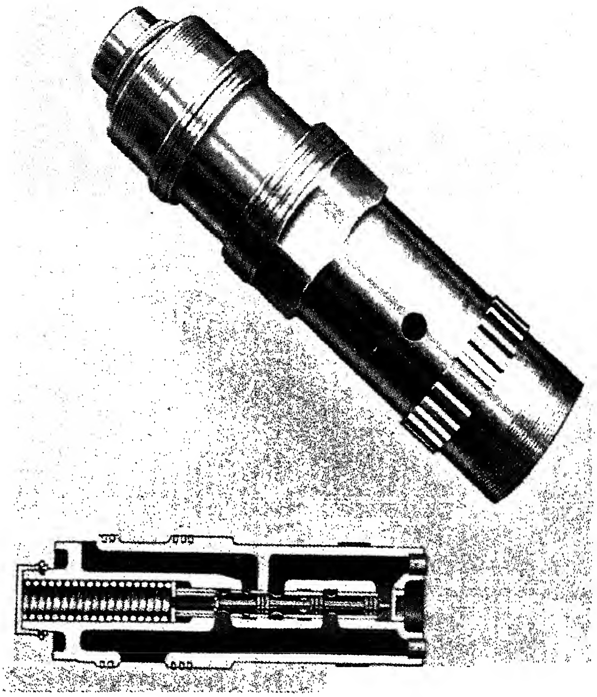


Fig. 21.—HYDROMATIC AIRSCREW. DISTRIBUTOR VALVE ASSEMBLY

drain through the drive gear shaft just as the engine reaches the speed for which the governor is set.

It should be noted that the relief valve in the governor is so interconnected with the engine oil system that it is held closed by the force of the relief valve spring plus the engine oil pressure, whatever this may be. Thus, the effect is to provide a maximum pressure difference across the airscrew piston equal to the relief valve spring loading, and by this means any adverse effects on the operation of the airscrew by variations in engine oil pressure in any one engine or between engine types are eliminated.

The distributor valve assembly, which consists of an aluminium housing and a spring-loaded distributor valve, is screwed at one end into the end of the airscrew shaft, whilst the outer end is supported in a steel sleeve located in the piston.

Piston rings are fitted to maintain an oil seal between the front and back of the piston, and ports are provided in both the valve body and sleeve to permit displacement of the oil actuating the piston.

Only in unfeathering is there any movement of the distributor valve, which then acts as a change-over switch ; at other times the valve body merely provides passage for the two oil supplies.

Range of Movement and Blade Angle Adjustment

In place of the 20° movement of the counterweight type, the hydromatic airscrew provides a range of 35° for constant-speed operation, and a further 45° of movement to the fully feathered position.

Because of varying helix angle and differing blade designs, the angle at which the blades will feather and the airscrew remain stationary in the airstream requires to be determined for each airscrew, and an adjustable

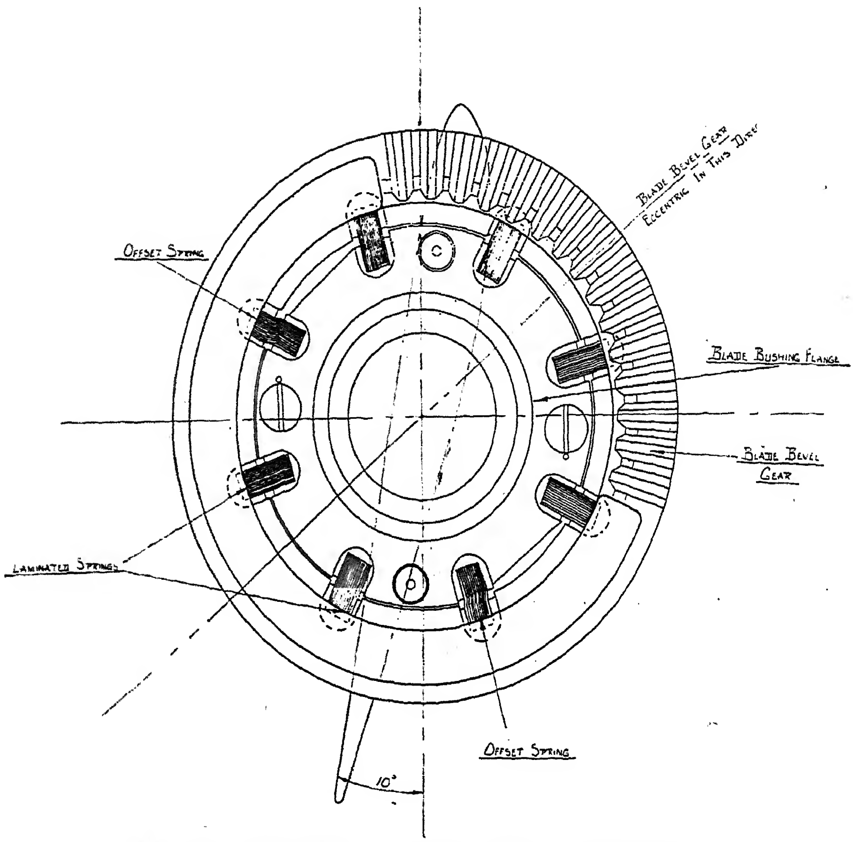


Fig. 22.—Arrangement of bevel gear on blade end

stop is provided to ensure that the blades cannot turn beyond this position.

At the inner end of the range, likewise, a stop is fitted to prevent the blades going to an unsafe angle should the constant-speed oil supply fail.

Both of these stops are fitted in serrated rings which are accommodated in a similarly serrated location provided in the flange of the fixed cam member in which they can be adjusted by steps of 1°, and where they make contact on either side of a block fitted between the teeth of the bevel drive gear.

Adjustment of the pitch angles is thus effected easily and conveniently for all blades by the one operation, and no basic adjustment of angle, such as was provided in the counterweight type of airscrew, is required.

The driven gear wheels on the blade ends are staked to the blade bushings by eight short packs of laminated springs, six of which lie radially between recesses machined in the flanges of these components and into which they fit.

Two of these spring packs, however, are offset in such a manner that

they tend to displace the driven gears towards the driving bevel on the moving cam member, and so provide a constant spring load, keeping driver and driven bevels in mesh, thereby obviating the necessity for fine adjustment on the depth of mesh.

The whole arrangement is calculated to insulate the operating mechanism from any fluctuating of the blade, and to eliminate backlash between the bevels.

Oil sealing is effected at the shanks of the blades, the joint of the dome assembly, at the barrel, and between the barrel and spider at the rear by special packing rings retained by gland rings, whilst the outlet between the airscrew shaft and the spider, which also is subjected to a feathering oil pressure, is sealed by means of a "U"-sectioned packing ring which is supported by the oil pressure.

The piston working in the dome is provided with a "T"-sectioned piston ring of fabric-bonded synthetic material which is clamped in position by a screwed junk ring.

The means of control between the pilot's cockpit and the constant-speed governor may be any of the systems approved or suitable for use with the counterweight type airscrew, but the governor itself is modified to provide pressure to force the airscrew into coarse pitch, and whilst suspending its normal operation, to permit the passage of high-pressure oil to feather and unfeather the airscrew.

The controls for feathering are provided separately and may take any one of several forms, depending, for example, upon the number of installations to be operated, whether individual or central control is specified, or mechanical, electrical, or hydraulic power is to be used.

They must all, however, be provided with an independent supply of oil at pressure capable of building up to 600 lb. per square inch, and means whereby the pilot may select and apply feathering or unfeathering pressure to any airscrew without delay or need for careful adjustment.

By using solenoids, as in the electrical system illustrated, pressure relief valves, and similar arrangements, much of the control can be made semi-automatic, and little complication therefore is added, nor is any difficulty likely to be encountered by a pilot in putting a quick decision into effect.

In previous articles endeavour has been made to draw an analogy between the airscrew and the transmission of a motor vehicle in order to demonstrate more clearly the effects of varying the pitch.

The fixed-pitch airscrew, for instance, was likened to a car without a gearbox, which, because it would have to be powered to surmount a specified gradient, would be overpowered for normal running, and therefore most inflexible and uneconomical for general use.

The two-pitch airscrew was compared to a car designed for normal economical use, with a single alternative gear to enable it to surmount a specified gradient—a much more economical vehicle albeit still rather wasteful on gradients less than the maximum. The two-pitch airscrew,

however, improves considerably upon the car performance by reason that an aeroplane can always choose the economical gradient.

The constant-speed airscrew provided the parallel of the infinitely variable gearbox, and gave a maximum of speed and a still higher index of economy over the widest variations of gradient with a considerable reduction of wear and tear.

The hydromatic airscrew adds the clutch, the overdrive, the freewheel, and a durability only equalled by the very best aero engine, or the most distinguished automobile.

No reverse has been provided, since only in a very few special cases would this be of advantage, and the analogy, therefore, is complete.

THE ELECTRICAL CONTROL OF THE HYDROMATIC AIRSCREW

THE hydromatic airscrew provides a very good example of the use of full electrical remote control on aeroplanes. Before describing the method of control and the circuits, it is necessary to know the purpose of the control.

As has been described elsewhere the hydromatic is a variable-pitch airscrew, that is to say, the blades may be moved at will during flight or at "take off," so as to give either a coarse or fine pitch. By being able to vary the pitch it will be seen that the airscrew can be made to operate at its highest efficiency for any particular condition.

For example, in taking off under heavy load, the airscrew would be set to a fine pitch, and then as the aeroplane became airborne the pitch would be altered to coarse. This variation of pitch is known as feathering, and the airscrew may be partly or fully feathered.

When fully feathered the edges of the blades are facing fore and aft, that is, in the line of flight.

Being able to fully feather is particularly useful on multi-engined aeroplanes, because in the event of serious mechanical trouble, such as a broken oil pipe, the act of fully feathering (after switching the ignition off) stops the engine, and as the blades are edge to the wind, they cannot "windmill" and so cause further damage to the engine.

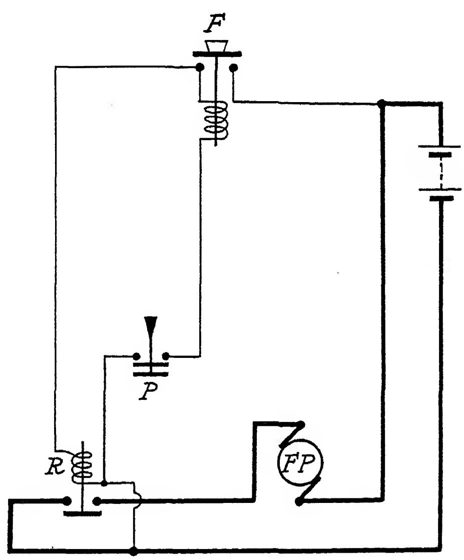


Fig. 1.—ELECTRICAL CIRCUIT FOR CONTROL OF HYDROMATIC AIRSCREW

F, feathering switch; P, pressure relief valve; R, motor solenoid switch; FP, feathering pump.

Essentials of the Electrical Equipment

The moving of the blades is done hydraulically at high

pressure, but the mechanism is driven and controlled electrically. Essentially, the equipment consists of a motor for driving the pump, a magnetic relay switch for closing the motor circuit, a feathering switch, a pressure relief valve having electric contacts attached, and finally a source of supply in the form of a 12- or 24-volt battery.

The Feathering Switch

Operation is initiated by the feathering switch, which must be mounted within easy reach of the pilot and yet not be in such a position that it can be moved accidentally. This switch is a specially designed "push-on" type, and is spring loaded so as to maintain the contacts normally open.

Also incorporated in the body of the switch is a solenoid, brought into action when the plunger is depressed, and so arranged that it keeps the contacts closed against the action of the spring. This allows current to flow around a solenoid winding of the switch connected in the motor circuit itself, thus starting the feathering pump, which operates until the airscrew is half feathered, when the pressure relief valve operates.

The electric contacts attached to this valve are connected in series with the solenoid of the feathering switch near to the pilot, and as soon as the pressure reaches a predetermined value, the relief valve opens these contacts, which open the solenoid circuit of the feathering switch. This in turn opens the solenoid circuit of the motor switch and so stops the pump. The circuit described is shown schematically in Fig. 1.

Heavy Cable is Required

To continue the feathering to its maximum, the feathering switch must be held in by hand until the airscrew is fully feathered. In flight, the time taken fully to feather is approximately 6 seconds, and the current taken by the motor 150–200 amperes at 12 volts. This large current naturally calls for heavy cables, either 248/·018 or 416/·018, depending on the length of the run.

Unfeathering

Having feathered, it may become desirable to unfeather, which is again done by means of the switch in the pilot's cockpit. The switch is closed as for feathering, but the hydraulic pressure is now applied to the opposite side of the feathering piston, and as soon as the blade has partly turned, the airstream commences to act on it and assists the pump in bringing the pitch back to normal.

Combining Feathering and Starting Circuits

When an aeroplane is fitted with electric-engine starting, a considerable saving in cabling can be effected by combining the airscrew feathering circuit with that of the engine starter, as these two circuits are not

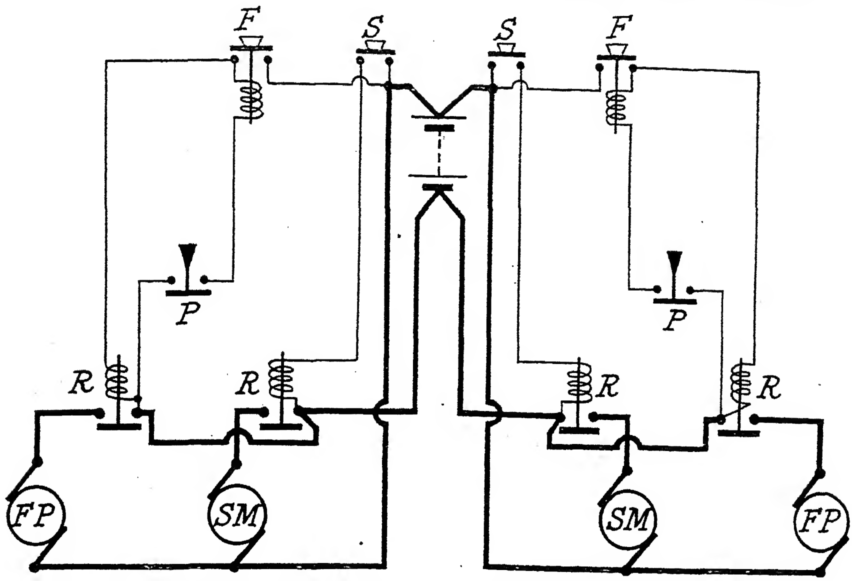


Fig. 2.—Combined feathering and electric-starting circuit

With two single-acting relay switches in the motor circuits of each engine.

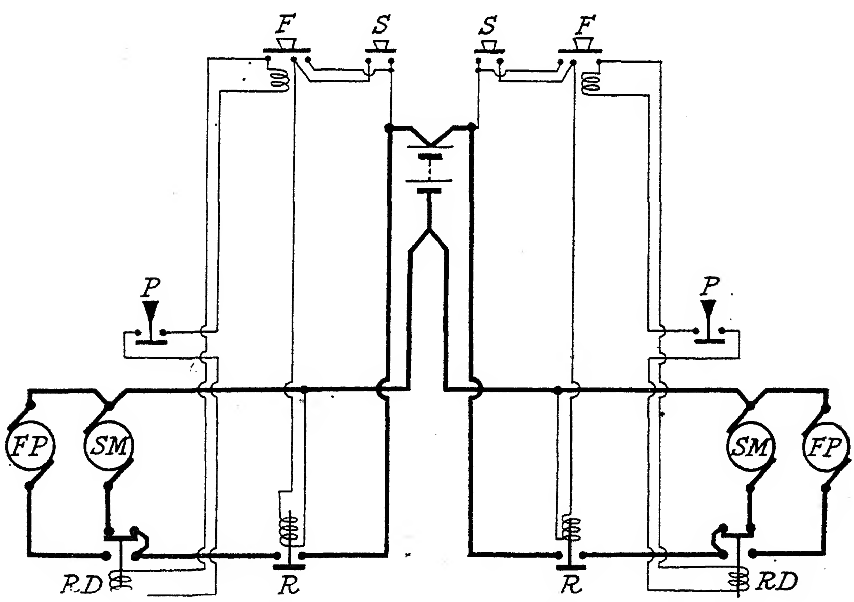


Fig. 3.—Combined feathering and electric-starting circuit

With one single-acting and one two-way solenoid switch in the circuit.

required at the same time. Fig. 2 shows a dual circuit of this nature for a twin-engined aeroplane with two single-acting relay switches in the motor circuits of each engine. Fig. 3 shows a similar circuit, but employing one single-acting and one two-way solenoid switch in the circuit.

Whichever circuit is adopted is purely a matter of choice, as neither has any outstanding advantage. In the case of Fig. 2 (single acting), it would be advisable to mount both the solenoid switches in the fuselage, otherwise the necessity would arise for a pair of permanently "live" heavy mains running along each wing of the aeroplane to the engines, but on the other hand switching is slightly simpler. With Fig. 3 (double acting), all relays can be mounted out of the way, in the engine nacelles. Referring to this diagram, it should be noticed that the feathering switch has three contacts, the object of which, when feathering, is to close the single-acting relay slightly before the double-acting relay is pulled over to the feathering contacts. The diagrams as drawn show the circuit ready for engine starting.

NOTES ON THE OPERATION AND CONTROL OF THE CONTROLLABLE-PITCH AIRSCREW

IN the previous pages we have described the general principle of the controllable-pitch and hydromatic airscrews, and have dealt in detail with the complete overhaul, installation, and maintenance of the former type.

In the following pages it is proposed to deal with the operation and control of the controllable-pitch airscrew after it has been installed on the aeroplane.

Preliminary Test after Installation

(*a*) Before running, the airscrew should be turned past a fixed point to check the track of the blades. An error of $\pm \frac{1}{16}$ in. is admissible; but if this amount is exceeded, it is an indication, either that the airscrew is not true on the engine shaft, or that one or more of the blades are outside tolerance on face alignment and the airscrew should in this case be rectified at the first opportunity.

(*b*) Check over all security fastenings. Where spinners are employed they will be fitted either wholly or in part after the airscrew has been installed and should be checked over for security of attachment as a last operation before the engine is run.

Inspection before First Flight Test

Before the first flight test, inspection should be made to ensure that the operation of pitch changing is normal. Service experience has shown that it is preferable to make the airscrew-blade assembly as tight as practicable during erection, because when the airscrew is rotating the centrifugal pull of the blades stretches the barrel sufficiently to free the assembly for proper operation in changing pitch. This test of operation should therefore be made by observing the pitch-change mechanism during the process of running up, and not by attempting to change the pitch of the airscrew blades by hand while the engine is at rest.

(1) Start the engine and run it up to about 900 r.p.m. for ten or twelve minutes, with the airscrew in fine pitch.

(2) Switch off the engine, and charge the airscrew with grease, using a special grease gun with the extension provided in the running tool kit.

If a pressure gun is available, this may be used, but care should be taken not to exceed the pressure of 2,500 lb. per square inch, because the blade plug is liable to be displaced by greater pressure.

(3) If, whilst the engine is running, any vibration is apparent which is not attributable to other causes, it may be due to uneven distribution of grease within the hub, and the grease gun should, in these circumstances, be applied again until either the vibration disappears or the hub is quite full, which condition is easily recognised by the solid feel of the grease gun.

(4) Check the pitch-changing mechanism whilst the airscrew is rotating. This can best be observed by noting the travel of the cylinder from a position in the plane of rotation. Any marked difference in the rate at which the airscrew changes pitch from coarse to fine or vice versa, after due allowance has been made for atmospheric temperature, etc., should be a reason for investigation.

Points to Remember regarding Change of Pitch

In observing the change of pitch, however, it should be borne in mind that, whereas hydraulic pressure changes the blade angle from coarse to fine pitch, centrifugal force acting on the counterweights is applied to change the angle in the reverse direction. Therefore, the latter change will be accomplished more rapidly at high engine r.p.m. because of greater centrifugal force. On the other hand, change from coarse to fine pitch will be more rapid at lower engine speeds, when, naturally, centrifugal forces are lower. Furthermore, it should be remembered that the change from coarse to fine pitch is accomplished more slowly on the ground than in flight, because the relative angle of attack of the blades is high, and the resulting aerodynamic reactions on the blades oppose pitch change in this direction.

(5) The throttle should be operated carefully when changing from coarse to fine pitch whilst checking revolutions on the ground, for the reasons given in "Operating Airscrew in Flight."

Operating Airscrew in Flight

Normally, the de Havilland controllable-pitch airscrew will change pitch in either direction as required, under all normal conditions, without any further attention from the pilot than the operation of the control.

The forces acting in combination to produce these effects are, however, all variable ; and acting sometimes in concert and sometimes in opposition, they may be employed either to retard the pitch change or to accelerate it in equal degree.

To appreciate the operation of the airscrew in flight, therefore, it is necessary to consider the effects of the various controlling forces under different conditions and in different attitudes of the aeroplane.

The first of these forces is the centrifugal effort of the counterweights, which is acting to hold the airscrew in coarse pitch against the couple which tends to turn the blades into the plane of rotation during the whole time the airscrew is revolving and whose effort varies directly as the square of the r.p.m.

The second force is the engine-oil pressure, which is maintained at a constant value by the engine relief valve, and, operating upon a fixed-diameter cylinder, produces a determinable pull acting against the force of the counterweights when oil is admitted to the cylinder. It will be apparent, in order that the airscrew shall move into fine pitch, that it is necessary to proportion the cylinder and oil pressure to overcome the maximum centrifugal force which may be developed by the counterweights.

The third force arises from the movement of the centre of pressure on the surface of the blade in accordance with the effective angle of attack —moving towards the leading edge when the angle is high and towards the trailing edge when the angle is low, and tending thus either to assist or retard the pitch change.

Fine Pitch

The best conditions for going into fine pitch, therefore, are low r.p.m. to reduce the opposing effort of the counterweights and as high an airspeed as possible in order to reduce the effective angle of attack and displace the centre of pressure of the blades towards the trailing edge. These are best effected by throttling back and putting the aeroplane in an attitude of glide.

Coarse Pitch

To change into coarse pitch it is desirable to increase the centrifugal force of the counterweights and to move the centre of pressure on the blades towards the leading edge, which conditions correspond to a high engine r.p.m. and an attitude of climb. In the last case, however, it will be clear that sustained climb will hold down the r.p.m., but the conditions can be met by maintaining a high airspeed and operating the airscrew control, at the same time putting the aeroplane into an attitude of slight climb.

Since two of the requirements in this last case are contrary, there will be an optimum set of conditions of airspeed, engine speed, and climbing angle, at which the airscrew will change pitch most promptly. These conditions can only be determined for each type by experiment.

It is necessary to land aeroplanes with the airscrew in the fine-pitch

position, especially where limitations of space or weather conditions make landing difficult or hazardous and maximum power and climb may be required in emergency to take off again.

When, however, the aeroplane has landed, the engine should be run up and the airscrew allowed to take up the coarse-pitch position before the engine is stopped.

Routine inspections and adjustments will be facilitated if the airscrew is left in this position, since the piston and cup leathers are then immediately under the cylinder head, where they are most accessible.

In addition, this practice will afford opportunities at the beginning and end of each flight to observe the airscrew actually changing pitch.

Possible Pitch-change Troubles

If, in the course of test, the airscrew fails to change pitch or is noticeably sluggish in either direction, the matter should be investigated, when the reason will usually be found amongst the possible troubles listed hereafter:

(1) *Complete failure of engine-oil pressure.*

(2) *Low or intermittent oil pressure*, resulting from defective relief valve, shortage of oil supply or, in cold weather, from cavitation in the engine supply pump.

(3) *The Control Valve.*—In particular the control valve is liable to lose its adjustment and either completely or partially blank one of the ports, thereby preventing admittance of oil to the cylinder or the escape of the oil from the cylinder. In the event of any of these faults occurring, the control system should be thoroughly overhauled in case stoppage of the inlet or drain has occurred. Ascertain if weaving of the wing in flight or other distortion of the structure can affect the adjustment of the control, which is satisfactory on the ground.

(4) *Pilot's Control.*—Examine this for possible failure to operate the control valve, either because of lost motion or the stretching of controls in flight as described above.

(5) *Counterweight Bearing-cap Race.*—Unlock and unscrew the counterweight cap, remove the counterweights, and inspect the cap race on the bearing assembly, which is located in the cam slot of the counterweight bracket, to ascertain that it has not been mounted incorrectly. The curved tracks or grooves in the round cap race must coincide with the curves of the ball cage.

(6) *Counterweight Bearing Shaft.*—Inspect clearances between the thrust washer and the back of the counterweight bracket to ensure that the counterweight bearing race assembly is not too tight.

(7) *Thrust and Ball Races.*—After considerable running time, thrust and ball races tend to become pitted in the coarse-pitch position and may slow up the rate of change.

(8) *Piston Leathers.*—Piston leathers overtightened or unevenly put on may jamb in the cylinder bore and resist movement of the cylinder.

The Question of Balance

The state of balance of any airscrew is most important, since any want of balance may not only induce vibration uncomfortable to the pilot and loosen connections and attachments, but may have even more serious effects.

The utmost care, therefore, is exercised throughout manufacture.

All component parts are produced to standard weights and moments within exceedingly small tolerances, whilst finally the completed airscrew is balanced on rigid and accurate knife-edges.

This static balance check, taken in conjunction with the checking of the blades for track, also serves to prove dynamic balance, since all components which gyrate around the axis of rotation are individually balanced for both weight and moment about that axis, and as each group revolves in a plane at right angles to the centre line, no disturbing couples can be set up except as the result of serious deformation in the airscrew.

Finally, aerodynamic balance is effected by carefully limiting the dimensions, areas, and angles of the blades—not excluding repaired airscrews—within close tolerances.

Correctly assembled, therefore, there is no reason why the airscrew should ever deteriorate in balance, since it deflects more uniformly under load than does a wooden airscrew, is not liable to blade distortion from climatic conditions, and has no fluid moisture content.

Should vibration develop in an installation which has previously been smooth in operation, therefore, it is only necessary to examine the blades visually and check their track at the tip—since deformation which might set up vibration will always be most apparent at the tip—when, if no damage is apparent, the airscrew can safely be ruled out as the possible cause.

The Controllable-pitch Airscrew in Constant-speed Installations

To convey a clear impression of application and functioning, the previous notes have dealt with the airscrew almost solely in two-pitch applications, but actually airscrews with 14° pitch range or more are usually employed under constant-speed control.

If a two-pitch airscrew in fine pitch be considered for a moment, it will be observed that the channel from the engine-oil system to the airscrew cylinder is open, and that the oil pressure is holding the blades in fine pitch against the effort of the counterweights, which are endeavouring to return the blades to coarse pitch.

The oil drain to crankcase is closed.

In moving the control towards coarse pitch, a stage is reached, at about half-travel, when the oil supply from the engine is shut off, but the

oil drain is not yet open, so that any oil remaining in the cylinder will be trapped and will prevent the blades returning to full coarse pitch.

A slight movement of the control from the position in the direction of coarse pitch will release oil from the cylinder, so increasing the pitch and decreasing the r.p.m., whilst a similar movement in the reverse direction will admit oil to the cylinder, so decreasing the pitch and increasing the r.p.m.

If, therefore, the pilot were provided with a spring plunger on the pitch-change lever, or other arrangement on which could be felt the mid-position of the valve at which both inlet to and outlet from the airscrew are closed, he could obtain some measure of constant-speed control by following up each change of power, height, or airspeed by an appropriate movement of his lever.

Automatic Governor

Such an arrangement would be impractical, because of the skill and attention required of the pilot ; but the control is easily effected by means of an automatic governor.

In constant-speed applications, therefore, the de Havilland controllable-pitch airscrew is provided with a governor driven from the engine, which varies automatically the pitch of the airscrew blades as required to maintain constant engine speed.

It thus enables the engine to develop full power continuously, without regard to the altitude or attitude of the aeroplane or to its forward speed through the air, throughout take-off and climb, up to the critical altitude of the engine.

The governing unit is effective over a wide range, and any speed below or above the rated engine speed falling within the range can be selected by the pilot, who is provided with a control lever working in a quadrant graduated for increase and decrease in r.p.m.

Power is varied by means of the engine-throttle control in the conventional manner, but within the constant-speed range no change in r.p.m. occurs, since normal movement of the throttle lever is followed immediately by an automatic change of blade angle, and the variation in power which results is only to be observed in changes in the manifold pressure (or boost) and airspeed.

The safety features of the controllable-pitch airscrew are all retained in the constant-speed application, and the counterweight adjusting screws are set to limit the blades to safe angles which they cannot exceed in flight.

Safe Angles

These positions of the blade, which are known as "positive coarse pitch" and "positive fine pitch" respectively, occur at each end of the

constant-speed range, and can be selected by the pilot at will by passing the constant-speed lever through the range of controlled speeds to either end of the quadrant. Positive fine pitch, however, is only used in prototype installations for test purposes, and in production aeroplanes it is usual to omit this setting to enable the control to hold the engine within maximum permissible revolutions under all normal conditions of flight.

With the airscrew in positive coarse or fine pitch, the governing action of the control unit is suspended and engine revolutions will vary with throttle movement in the usual manner.

In cases where neither automatic mixture control nor a fuel/air ratio indicator is provided, the mixture may be adjusted periodically by putting the airscrew into positive coarse pitch and operating the mixture control as explained in further detail under " Control."

On the other hand, where automatic controls for both mixture and power (boost) are employed in conjunction with the constant-speed airscrew, the engine will hold any preselected revolutions and power from take-off up to critical altitude without further adjustment.

Such an installation not only relieves a pilot from the need to adjust his power, revolutions, and mixture strength at frequent intervals and of all anxiety for his engine, but it also permits a more economical fuel consumption than could be obtained safely by manual adjustment.

All de Havilland airscrews are essentially constant-speed airscrews, and where they have been fitted for two-pitch operation, they can be converted to constant-speed operation by making provision for mounting the constant-speed unit and adding the pilot's control.

In some few instances it may be desirable to provide a slightly increased pitch range in the airscrew to derive the maximum advantage from constant-speed operation, and where the range of speed is much increased, it may be desirable to exchange the counterweight caps, but in many cases no alteration to the airscrew will be required.

Control Unit for Constant-speed Operation

The control unit for constant-speed operation is simple and robust in design, and consists of a small gear-type boost pump, which is fed from the engine main oil supply, and which delivers oil under pressure to the airscrew through the airscrew shaft.

In the unit with the boost pump is a spring-loaded governor, which is driven from the crankshaft through gearing, and actuates a small piston valve which controls the flow of oil to and from the airscrew cylinder by admitting oil when the speed falls and so reducing the pitch of the blades and vice versa.

The pilot's control is effected by preloading the governor spring to any chosen value indicated on the r.p.m. indicator or on a scale marked on the control quadrant.

The ratio of the drive between crankshaft and constant-speed unit is

determined by the rated speeds of the engine in relation to the characteristics of the unit, which has a control range of 2,800–1,000 r.p.m. at the governor spindle. In the majority of installations the whole of this governing range is not required, and means are provided for restricting it to the specific requirements of individual installations. This restriction of the governing range simplifies the arrangement of the pilot's control system.

For most installations it is recommended that at the maximum rated speed of the engine in level flight, the constant-speed unit should be geared to run at a speed of 2,520 r.p.m., which is 10 per cent. less than the upper effective limit of 2,800 r.p.m., but this rule is varied for special applications in which the operational requirements are abnormal.

Whilst the constant-speed unit is proportioned to operate the largest-size airscrews, it only weighs about 4 lb., and the saving of weight which might be effected by introducing alternative sizes with reduced outputs for smaller airscrews is completely outweighed by the advantages of maintaining 100 per cent. interchangeability, and only one size, therefore, is manufactured. All units can be supplied to run either clockwise or counter-clockwise, and any unit can be altered from one direction of rotation to the other very quickly.

The advantages to be obtained from constant-speed operation are most apparent in the case of high-performance aeroplanes and supercharged engines, which usually employ reduction gears and require very coarse angles on the airscrew for level flight.

On the other hand, comparatively small angles must be available for take-off, and it occurs, therefore, that the range between coarse and fine pitch is so large for this type of aeroplane that it becomes increasingly difficult for the two-position airscrew to give a satisfactory performance between the extreme conditions.

Moreover, it will be apparent that, whilst there are three important sets of conditions to be catered for in taking an aeroplane to operational altitude, the two-position airscrew provides only two pitches to meet these requirements. There is no difficulty in adjusting such an airscrew to obtain maximum efficiency both at take-off and in level flight at altitude, but it is sometimes a problem to decide the best provision for the third condition—climb.

If, for instance, the airscrew is adjusted to allow the engine to develop its full climbing horse-power at the moment of leaving the ground, it will not be possible to continue to climb in fine pitch at this power, as at optimum climbing angle the engine would exceed its rated r.p.m. unless it were throttled down, thereby reducing the effective thrust and rate of climb.

If, on the other hand, the aeroplane is climbed in coarse pitch, the effect at low altitudes is to hold down the r.p.m., and again the engine is prevented from delivering its rated power.

The question is further complicated by reason that in neither of these cases are the conditions stable, owing to the change of atmospheric pressure with altitude; and it is necessary, therefore, to adjust the throttle at intervals to maintain the desired r.p.m.

In practice some compromise is usually made in fixing the angles of a two-pitch airscrew to provide the best possible performance under conditions specified in the order of relative importance, and not infrequently the final settings are decided upon only after a series of tests.

Aeroplane Performances with Constant-speed Control

The manner in which constant-speed control provides a solution to this problem is best illustrated graphically, and a series of calculated performances on a typical high-performance aeroplane have been plotted in graph form in Figs. 1, 2, 3, and 4 to show the thrust horse-powers available with fixed-pitch, two-position, and constant-speed airscrews in various conditions of flight.

Since the object is to compare the efficiencies of the airscrews, a basis of constant horse-power has been adopted in preference to one of constant boost, as with the latter system there is progressive increase in output of about 1·1 per cent. for each 1,000 ft. of altitude arising from reducing back pressure, which adds a varying factor to the diagrams.

Constant horse-power implies that from sea-level to critical altitude the engine will be operated to give a constant and steady power, so that the thrust horse-power indicated at any point on the curves is more directly a measure of the efficiency of that particular airscrew under the conditions obtaining.

The data are derived from a twin-engined aeroplane having a maximum speed of 250 m.p.h. at rated power at an altitude of 10,000 ft., which is also the rated altitude of the engines.

At rated power the speed at sea-level is 226 m.p.h.

For maximum climb at rated power the speeds are 125 m.p.h. and 138 m.p.h., at sea-level and at rated altitude respectively.

Take-off speed is taken as 65 m.p.h. at sea-level.

The engines are rated at 750 horse-power for 2,500 r.p.m. at 10,000 ft., whilst the cruising limits of operation are taken as 75 per cent. rated power and 91 per cent. rated speed.

The fixed-pitch, two-pitch controllable and constant-speed airscrews used in the comparison are all three-bladed and identical in size and shape.

The diameter has been selected to provide the best compromise performance for all conditions of flight, whilst both the fixed-pitch airscrew and the coarse-pitch angle of the two-pitch controllable are set for maximum speed in horizontal flight at 10,000 ft.—the rated altitude.

The fine pitch of the controllable two-pitch airscrew is adjusted for

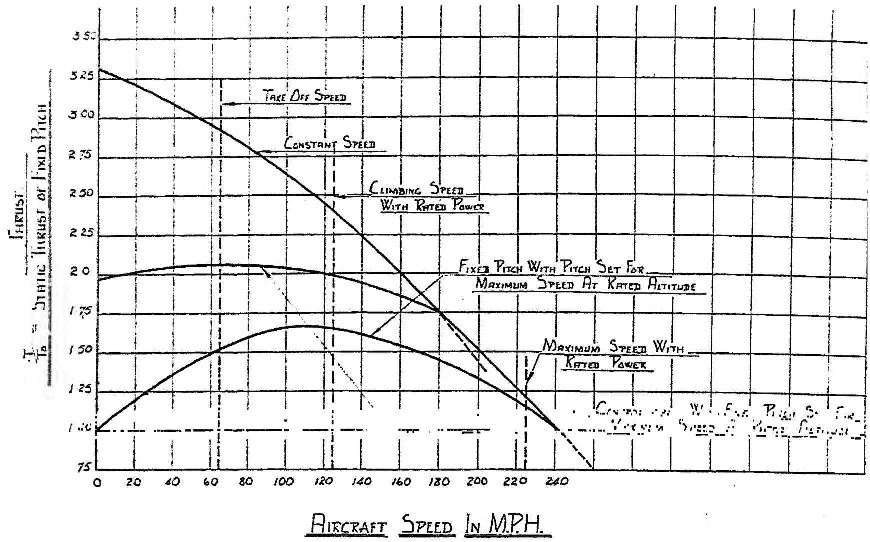


Fig. 1.—THRUST VARIATION AT SEA-LEVEL

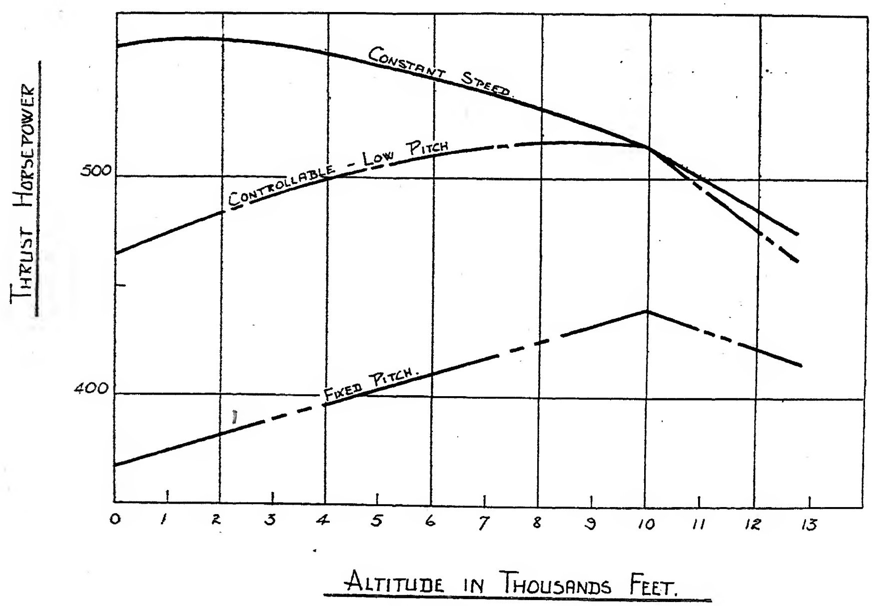


Fig. 2.—COMPARISON OF CLIMB

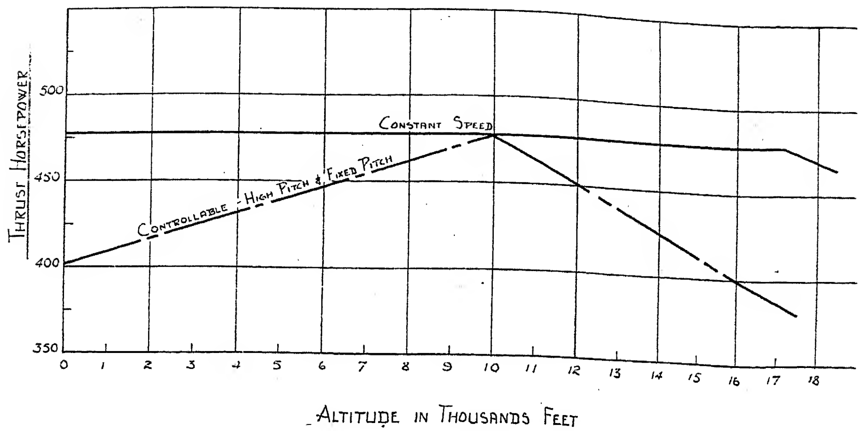


Fig. 3.—Comparison of cruising powers

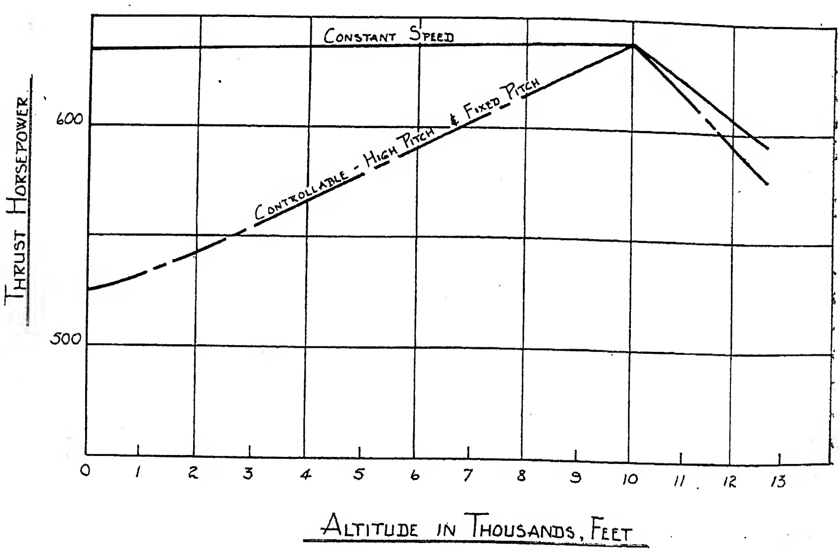


Fig. 4.—Comparison of maximum powers

maximum climb at rated altitude for the purpose of more direct comparison, though normally the setting would be made for take-off or climb at sea-level.

Performance at Take-off

In Fig. 1 the effective thrusts of the three airscrews have been plotted in ratio to the thrust of the fixed-pitch airscrew for various airspeeds at sea-level, with the engine operating at maximum permissible boost.

It will be observed that the average thrust of the constant-speed airscrew is about 60 per cent. more than that of the controllable and 150 per cent. more than the fixed-pitch airscrew between 0 and 65 m.p.h.

Advantages at Take-off

These figures are a direct measure of the difference in acceleration between the airscrews, and give a very clear picture of the advantages attending the use of the constant-speed airscrew at take-off.

Performance at Sea-level

The thrust variation is shown for speeds up to 240 m.p.h. It is clearly apparent that the constant-speed airscrew provides a much greater thrust than either the fixed-pitch or the controllable airscrew throughout the entire speed range except for two speeds. In one instance, at about 178 m.p.h., the constant-speed airscrew assumes the same angle as the controllable in the fine-pitch setting; in the other, at about 248 m.p.h., it attains the same angle as the fixed-pitch airscrew. For the controllable and fixed-pitch airscrews at speeds in excess of 178 m.p.h. and 248 m.p.h. respectively, the thrust falls rapidly, due to the necessity of throttling the engines to prevent overspeeding.

The speeds at which the constant-speed thrust is the same as that developed by each of the other type airscrews do not correspond to the climbing and maximum speeds, but are in excess of them, because the airscrews were set for these conditions of operation at rated altitude and not at sea-level, and therefore have a greater angle than would be required for the corresponding conditions of operation at sea-level. The advantage of the constant-speed over the controllable and fixed-pitch airscrews in climb and at maximum speed at sea-level is clearly indicated in comparing the thrusts available at approximately the climbing speeds and the maximum speeds which would be obtained with each of the three airscrews.

Performance during Climb

Fig. 2 shows the variations in thrust horse-power available in climb as the altitude increases, when the engine operation is such that rated power is available at rated speed throughout the climb.

The constant-speed airscrew has a very considerable advantage at sea-level, where it provides about 20 per cent. more thrust horse-power than the controllable and 35 per cent. more than the fixed-pitch airscrew, both of which are set for altitude operation.

This difference diminishes as altitude is increased, until at rated altitude, for which the blade angles of the controllable are set, the thrust horse-power is the same for both the variable airscrews.

At altitudes above rated, the thrust horse-power provided by the constant-speed airscrew falls off proportionately to the reduction in power of the engine above critical altitude, due to altitude effect.

Similarly, the power available with the controllable airscrew falls off at a faster rate, as the fine-pitch angle is too coarse above critical altitudes to permit the airscrew to turn at rated speed, and to this loss in thrust horse-power arising directly from the airscrew must be added the loss resulting from the decrease in speed below the rated level.

The constant-speed airscrew gives about 50 per cent. more power at sea-level and about 16 per cent. more at rated altitude than the fixed-pitch airscrew, the blades of which are set, not for climb, but for maximum speed at altitude.

The decrease in thrust horse-power available with the constant-speed airscrew at the more considerable altitudes is due in part to the decrease in the efficiency of the airscrew, which requires an increased diameter to maintain the optimum climb performance.

It is noteworthy, however, that on the constant-boost basis the increase in brake horse-power with altitude up to critical more than compensates for the falling-off in airscrew efficiency.

Performance during Cruising

Fig. 3 shows the variation with altitude of thrust horse-power available for cruising. At sea-level, the constant-speed airscrew provides about 19 per cent. greater power than the controllable (in high pitch) and the fixed-pitch airscrew. This difference diminishes with altitude until, at rated altitude, the thrust powers are the same. Above rated altitude, the difference increases because of the necessity for throttling the engine to prevent overspeeding with the controllable and fixed-pitch airscrews, until at cruising critical altitude the thrust power available with the constant-speed airscrew is about 25 per cent. greater than with the other airscrews.

The reason that the difference in thrust powers is zero at rated altitude is because the cruising rating is taken on the rated power "airscrew load curve." This permits full cruising power to be developed at rated altitude at the same blade-angle setting as will give rated power and r.p.m. in level flight. Thus the angle settings for the cruising condition will be the same for all three airscrews at rated altitude.

The constant-speed airscrew develops substantially constant thrust powers up to the engine critical cruising altitude of 17,200 ft., as the airscrew efficiency is practically constant and since it is possible to maintain full cruising engine power by opening the throttle as the altitude is increased. Above this altitude the engine is operating at full throttle and the power drops off as the altitude is increased.

This chart shows clearly the great advantage of the constant-speed airscrew over the controllable and fixed-pitch airscrews, especially for altitudes greater than the rated altitude of the engine.

Maximum Speed

Fig. 4 shows the variation in thrust horse-power with altitude for the maximum-speed condition in a similar manner as for the cruising condition. It clearly shows the advantage of the constant-speed airscrew over the other two. At sea-level the constant speed provides about 21 per cent. more thrust power. This difference gradually diminishes as rated altitude is approached and is zero at that altitude. Above rated altitude, the difference increases for the same reason as in the case of the climb condition.

These calculations demonstrate clearly the advantage to be gained in all conditions of flight by the use of constant-speed control, and indicate the necessity for such a device on the high-performance aeroplanes now being designed and built.

For take-off the pilot may utilise all the power which the engine manufacturer allows for safe operation of the engine. This is accomplished by opening the throttle to give the maximum permissible manifold pressure and adjusting the constant-speed control to give full take-off r.p.m. The constant-speed airscrew will hold this r.p.m. steadily, irrespective of the change in the forward speed of the aeroplane as it increases from zero at the start of the take-off to flying speed. Therefore, with manifold pressure and r.p.m. unchanged, this full power is utilised throughout the take-off run and into the climb.

Where different take-off and climb r.p.m. are specified, it will be necessary to readjust the constant-speed control after take-off, but whilst climbing to cruising altitude, the full rated or climbing power of the engine is available at all flying speeds and all altitudes by independent control of the manifold pressure (throttle) and the r.p.m. (constant-speed control). With supercharged engines there is more decided increase in the rate of climb to cruising altitude compared with the corresponding performance using a fixed-pitch or two-position controllable airscrew.

Cruising and High Speed

When cruising altitude is reached and the pilot wishes to reduce the power to that desired for cruising, it is simply required to set the constant-speed control to the corresponding r.p.m. and adjust the throttle to the

cruising manifold pressure. A change in altitude, of course, necessitates readjusting the throttle to correct for the corresponding change of manifold pressure, but the r.p.m. will remain unchanged, being automatically taken care of by the constant-speed control.

Cruising speed and top speed are both markedly improved above and below critical altitude for cruising compared with the performance when using a fixed-pitch or two-position controllable airscrew. Flight tests in a typical case, for instance, have shown that the improvement at sea-level was approximately 15 m.p.h. with the constant-speed airscrew. At critical altitude the constant-speed airscrew would, of course, give the same performance as either a fixed-pitch or a two-position controllable airscrew adjusted for that altitude, but above that altitude the improvement in cruising speed and top speed would again appear with the constant-speed installation.

Demonstration and Exhibition Flying

For demonstration and exhibition flying the constant-speed airscrew is of the utmost value, since it enables the engine to deliver its full power whilst the aeroplane is manœuvring or carrying out aerobatics, and it eliminates the harmful effects of engine overspeeding in dives and retards undesirable rise of cylinder mean effective pressure in zooms of full-throttle climb. In formation flying the speed of each aeroplane is controlled by throttle in conventional manner, but the change of power is not accompanied by any change of r.p.m. and only the manifold pressure and airspeed vary.

Multi-engined Aeroplanes

On multi-engined aeroplanes the need to control the r.p.m. of the engine is more exacting than in the case of a single-engined aeroplane, since any slight variation becomes apparent at once by the engines falling out of synchronism. The ability of constant-speed airscrews to maintain synchronism is extremely good, and multi-engined aeroplanes carrying two, three, and four engines demonstrate this fact continually.

Sudden "Burst" of Throttle on One Engine

The most exacting condition to which the constant-speed airscrew can be subjected is the sudden change in blade pitch required to accommodate a "burst" of throttle on one engine with the remaining engines running steadily in flight. In this circumstance the airscrew responds so quickly that no more than six or seven seconds are required to return the engine speed to synchronism with the other engines. Only a momentary reduction of engine speed occurs when suddenly "cutting" one throttle on a multi-engined aeroplane in flight, and it is most difficult to detect any shade of variation in engine speed as the result of climbing suddenly,

diving, or going into sharp turns. Multi-engined aeroplanes equipped with constant-speed airscrews, furthermore, are little affected by rough air when once the engines are synchronised and the throttles can be readjusted as desired without putting the engines out of phase. Thus, when climbing or descending, the throttles can be moved to adjust the boost without alteration to engine revolutions.

Economy

In multi-engined aeroplanes used in long-distance flying, great economy is derived from the use of constant-speed airscrews, since they permit the engines to be operated under the most economical conditions during climb and descent from cruising altitude as well as while cruising at intermediate altitudes. In descending from cruising altitude, it is possible to increase the airspeed of the aeroplane considerably without change of engine r.p.m. or power.

In case of the failure of one engine of a multi-engined aeroplane, the pitch of its airscrew should always be adjusted to "positive coarse pitch" in order to reduce the drag of the rotating airscrew.

With the constant-speed airscrew there is no longer the limitation imposed by the necessity to fly at powers specified by the old familiar "airscrew load curve." The pilot may select any combination of engine speed and manifold pressure within the operating range. It is a well-known fact that certain engine speeds induce resonant vibrations in various parts of the airframe structure, and that these vibrations not only are very annoying, but in some cases may be actually dangerous. With the constant-speed control it is possible to set the engine speed for the smoothest operating conditions, and this speed will be maintained automatically by the control.

Another advantageous feature of the constant-speed airscrew which may not at first appear favourable is in fact a benefit in time of need. When gliding or coming in for a landing, the airscrew automatically goes towards fine pitch and with slight opening of throttle a moderate amount of power is available without overspeeding the engine. Should emergency demand considerable power, however, the constant-speed unit brings the speed back to normal with a perceptible acceleration of the aeroplane as the blades go to a higher pitch and convert the kinetic energy of rotation into thrust.

CONTROL

Mixture and Boost Control

The considerable advantages in performance which have accrued from the constant-speed control have intensified the efforts of designers to produce efficient forms of mixture and boost control in order that the full benefits of automatic operation might be realised.

Already considerable progress has been made, and many forms of automatic or semi-automatic control have been applied and others are in process of development.

Where these complementary controls are fitted in a constant-speed installation and no difference between take-off and climbing boost is specified, the pilot can select his r.p.m. on the ground, and from the moment he opens the throttle to take off until he reaches critical altitude his engine will turn at constant speed, deliver the rated power for that speed, and adjust its fuel consumption appropriately throughout, constantly changing altitude without further attention.

This is a considerable relief to the pilot in a straight climb to high altitude, but is of far greater moment where evolutions, contours of the country or weather conditions require frequent alterations of altitude and speed, besides effecting, in the last-named circumstances, an economy of fuel and engine life which could not possibly be attained by manual operation of the controls.

In some installations the mixture strength is computed by means of a special form of exhaust-gas analyser, which indicates electrically the proportions of the main constituent gases in the exhaust and so enables the pilot to adjust his mixture at intervals without disturbing other controls.

Where none of these automatic or semi-automatic controls has been provided in a constant-speed installation, the regulation of boost (by means of the throttle) and mixture strength (through the hand-operated mixture control) will devolve upon the pilot.

Reference has been made previously to the fact that with constant speed in operation, no appreciable variation of engine revolutions occurs. even through considerable movement of the throttle lever; it will be apparent therefrom that the conventional method of adjusting the mixture strength (by reference to the revolution indicator) cannot be used whilst the installation is under constant-speed control.

It is necessary, therefore, to discontinue the constant-speed control and "fix" the airscrew in the positive coarse-pitch position, which is attained with the control lever at its extreme position beyond the low-speed end of the governing range, when the piston valve is positively held in the fully open position by a shoulder on the control-spring plunger and so releases the oil from the airscrew cylinder.

It is necessary in these circumstances to limit the full coarse-pitch setting to a value which is not much greater than that required for normal horizontal flight, and in most installations the stop nuts in the airscrew counterweight assemblies will be set to give a coarse pitch slightly in excess of that required to enable the unit to govern the r.p.m. in level flight at cruising altitude with cruising power.

Changing over to positive coarse pitch in these conditions will reduce the r.p.m. somewhat, and changes in mixture strength or throttle position

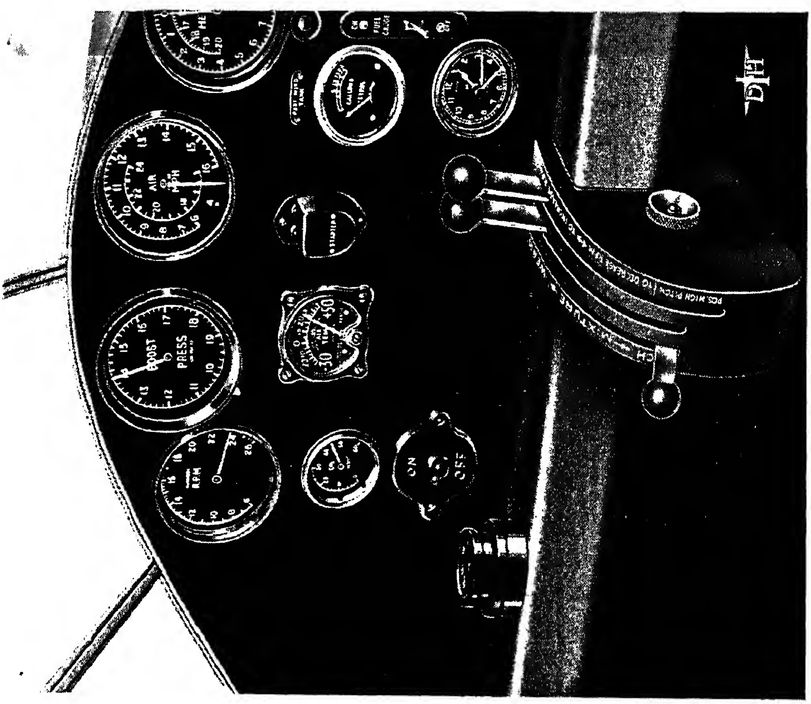


Fig. 5.—POSITION OF CONTROLS—TAKE-OFF

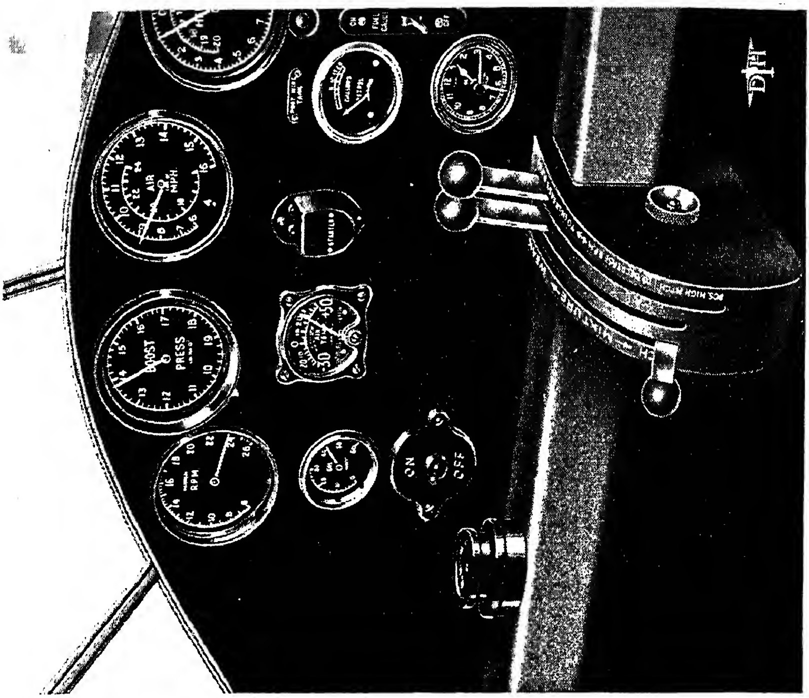


Fig. 6.—POSITION OF CONTROLS—FULL-THROTTLE CLIMB

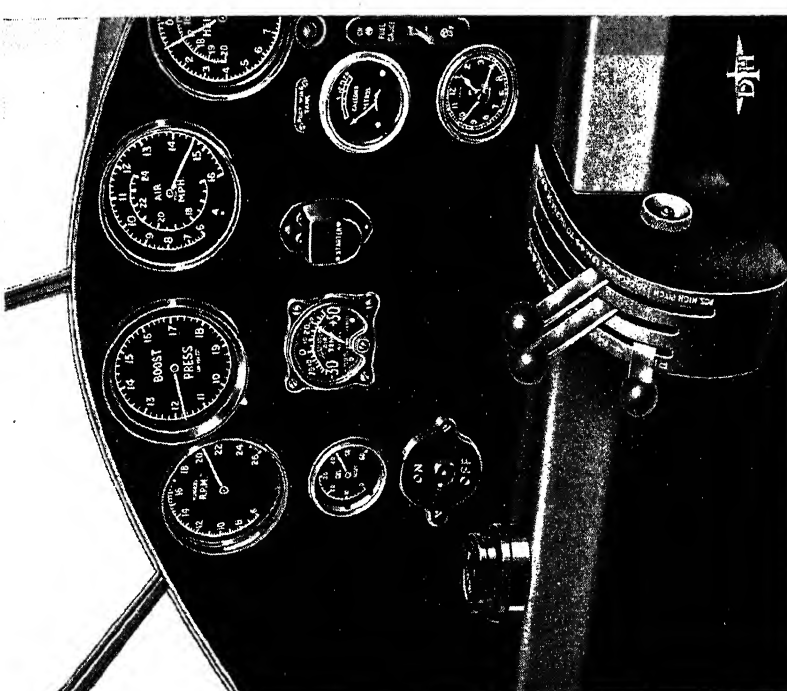


Fig. 7.—Position of Controls—Level Cruising at 1,000 ft.

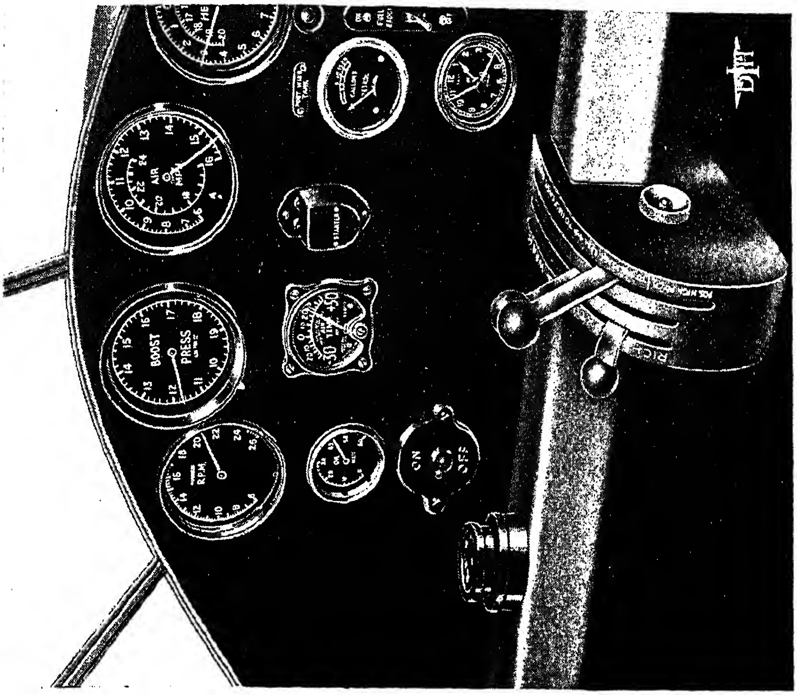


Fig. 8.—Position of Controls—Level Cruising at 3,000 ft.

will then be apparent on the revolution indicator, but the pilot should adjust his mixture without touching the throttle and then return the constant-speed control to the required setting.

It is important that the throttle remains unchanged whilst these adjustments are being made, as the carburettor adjustment may not be equally correct for different throttle settings.

A further use for the positive coarse-pitch control position is that, in the event of the failure of the airscrew oil line, the control allows the pilot to shift the airscrew to positive coarse pitch, which shuts off the flow of oil and prevents loss from the engine-oil supply and ultimate engine failure.

Positive fine pitch also is used for engine testing or on prototype aeroplanes where it is desired to check engine revolutions on the ground or test bench, but it will not often be required to run the engine under positive fine-pitch conditions in flight.

Manipulation of Controls

The manipulation of controls in constant-speed installations to produce the foregoing effects is a matter requiring some care and forethought until the pilot has become accustomed to the redistribution of the information afforded by some of his instruments and to the " feel " of the aeroplane in various conditions of flight.

Figs. 5, 6, 7, 8, and 9 show the position of these controls in a typical installation in various combinations, together with the recordings of the instruments resulting jointly from the settings of the controls and the attitude of the aeroplane in each case.

In this installation both mixture and boost are hand-controlled and the engine is rated for 2,100 r.p.m. at 11·7 lb. per square inch absolute manifold pressure at 6,000 ft.

For take-off and short-period climbs, r.p.m. are limited to 2,400 at full throttle.

It will be observed that, whereas the conventional two-pitch control of the " push-pull " type is pressed forward for high pitch and vice versa in order that it may " follow the throttle " and accord with general usage—the constant-speed airscrew is reversed and is in fine pitch with the control advanced.

This arrangement has been made on similar reasoning, for the constant-speed control is almost solely concerned with revolutions and by moving it in the same sense as the throttle the association of ideas is maintained and there is less probability of mistake.

Furthermore, since the lever may be mounted in the same quadrant and has a similar range of movement for some of the most frequently used positions, it will often be a convenience to be able to move them together.

In altering the throttle position or making adjustments to the constant-speed control, it is essential that the levers be moved firmly but without haste.

Pilots are reminded that the governing function of the constant-speed unit is initiated by small variations in the speed of the engine and that the sensitivity of the device has been applied to the smoothing out of these variations, which, under normal conditions of flight, occur relatively slowly and are of small amplitude.

Where, however, both a considerable rate of change and amplitude are introduced artificially by sudden movement of the controls, the lag in operation, which is not discernible under stable conditions, will also be considerable, and may give rise to an undesirable fluctuation of speed before it is finally damped out.

Similarly, the balance of speed and power is more susceptible to disturbance when the aeroplane is gliding than when it is in climb or level flight, and for the same reason the speed will not, as a rule, be so closely governed during a glide or power descent.

Flight Tests with Prototype Installations

(1) Where possible, the cockpit control should be rigged so that both positive coarse- and positive fine-pitch positions can be obtained on the governor. (For installations on which the positive fine-pitch position cannot be obtained, read " End of control lever travel towards fine-pitch position " for " Positive fine position " throughout.)

The airscrew pitch settings should at first be adjusted so that:

(*a*) The coarse pitch is that already established or estimated for cruising at the highest altitude at which cruising boost can be maintained.

(*b*) With the constant-speed control in the maximum r.p.m. position, the fine-pitch stop nuts limit the engine speed to a value 15 per cent. less than the maximum permitted for take-off. If this involves reducing the static r.p.m. below the specified minimum take-off r.p.m. of the engine, the engine and airscrew manufacturers should be consulted as to a suitable rating for the first take-offs or the advisability of using a special fuel to permit the low r.p.m. Alternatively, if settings have already been established for two-pitch operation, these settings should be used.

(2) Before attempting flight, the operation of the installation must be checked repeatedly as follows:

(*a*) Exercise the airscrew as a normal two-pitch installation. Set the governor control to positive fine pitch. Open the throttle to a position giving not more than the value of boost pressure permitted for economical cruising. Operate the governor control several times between positive coarse and positive fine pitch. The airscrew should move smoothly and without hesitation in both directions.

(*b*) Exercise the airscrew under constant-speed conditions. The governor control should be moved back slowly from the positive fine-pitch position until the r.p.m. just begin to fall. Continue the movement

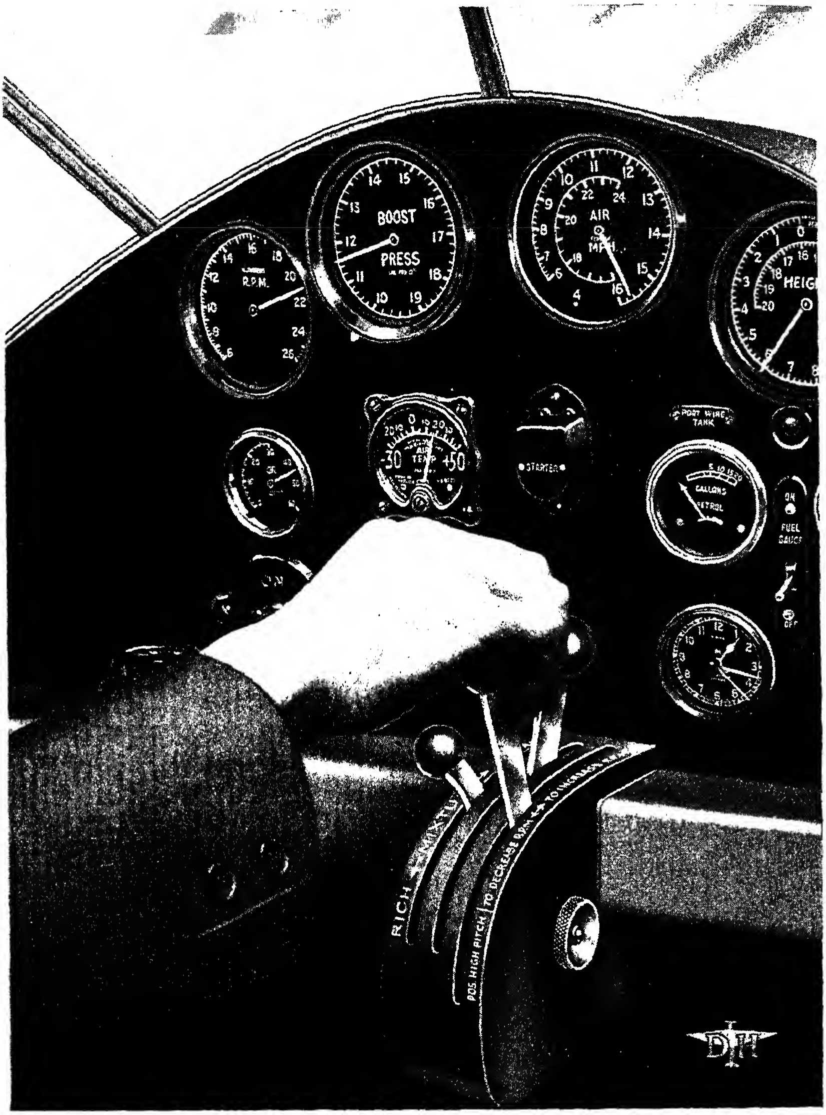


Fig. 9.—Position of controls—level cruising at 6,000 ft.

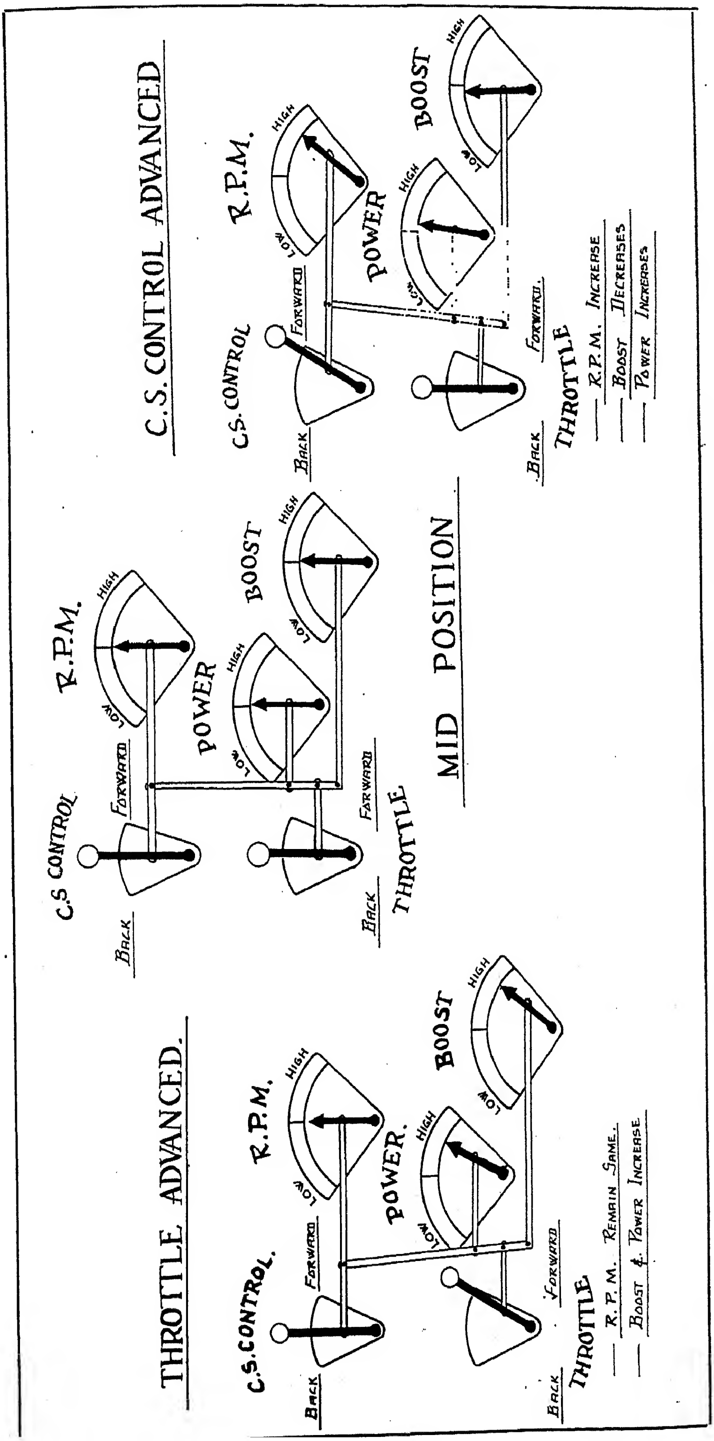


Fig. 10.—INTER-RELATION OF SPEED, POWER, AND BOOST

until the speed drops about 100 r.p.m., when the response of the governor to changes of throttle opening may be tried, but care should again be exercised that economical cruising boost is not exceeded.

A sudden change in throttle position will cause a surge in speed, but the r.p.m. should then readjust quickly and without hunting. The same effect is to be expected, but to a lesser degree, when the governor setting is altered.

This test should be repeated with the constant-speed control set for cruising r.p.m.

(3) With the above tests satisfactorily completed, the first flight tests may be made with the airscrew operating as a two-pitch airscrew.

Before take-off, several two-pitch operations should be made (as under paragraph 2*a*) to obtain a supply of warm oil in the airscrew cylinder.

Initially the aeroplane should be taken off and flown in a manner identical with that used for two-pitch installations. When sufficient height has been gained, the throttle should be readjusted to cruising boost pressure and the constant-speed control to cruising r.p.m. The pilot should then experiment with the controls to familiarise himself with the response of the governor to changes of airspeed, throttle, and r.p.m. settings.

(4) When the pilot and engineers are satisfied with the behaviour of the installation during the initial flight tests, adjustments may be made to allow constant speeding during take-off.

Firstly, the airscrew fine-pitch stop is to be set down so that the full r.p.m. at take-off boost are just obtainable on the ground, under governing conditions.

Important Note.—After the airscrew fine-pitch stops have been set so that full r.p.m. are obtainable, the constant-speed control should be re-rigged so the maximum r.p.m. are never exceeded, even when the control is in the foremost position. The maximum r.p.m. stop in some types of control systems is located in the cockpit and in others no special stop is provided and it will be necessary to readjust the major control members. The object of such adjustment is to make certain that the constant-speed governor never gets into the extreme high-speed position. This precaution is necessary to avoid the overspeeding of the engine which would result if the positive fine pitch which gave maximum revolutions at the start of the take-off were obtained in any flight condition.

Magnetos may be checked by setting the governor control to maximum take-off r.p.m. and closing the throttle until the speed falls about 50 r.p.m. The airscrew is then in fine pitch and will react to the operation of the switches as though of fixed pitch.

From the beginning of take-off and until a safe altitude is reached, any adjustment of r.p.m. and boost should be made very slowly, and it is usual to make all adjustments to boost prior to resetting the r.p.m.

In flight, the pilot should again try the effect of his controls in various positions in order that he may become thoroughly accustomed to their use.

First Flight Tests

(5) Before attempting flight, the operation of the installation must be checked repeatedly as follows:

(*a*) With brakes on and chocks under the wheels, exercise the airscrew on normal two-pitch operation from coarse pitch to fine and back again to coarse several times, taking care that economical cruising-boost pressure is not exceeded.

(*b*) Check constant-speed operation by moving the control lever to the end of its travel at the high r.p.m. end of the quadrant and open out the engine to a speed slightly under the maximum permissible static revolutions.

Adjust the throttle to give cruising-boost pressure, and at the same time readjust the constant-speed control until the unit is governing at cruising r.p.m.

Then open and close the throttle, first slowly to demonstrate that the unit is governing, and then quickly to make sure that it is governing within normal limits.

(6) When the installation is satisfactory in all the foregoing tests, normal constant-speed take-off may be carried out.

Both pilot and engineer should be thoroughly conversant with the above procedure before commencing any test, and it is most desirable that the details be freely discussed in order that the nature and purpose of each test may be clearly understood.

General Instructions while Flying

In dealing with constant-speed airscrews, it should be remembered that the throttle controls the engine-boost pressure and the constant-speed lever controls the r.p.m.

Whilst the r.p.m. remain constant, the power delivered by the engine will vary directly as the boost or absolute induction-pipe pressure.

Where, however, the r.p.m. are altered without change of throttle position, the power varies as the r.p.m., whilst the boost also varies but in the opposite sense.

The interrelation of the two controls and their effects may be studied from the diagram, Fig. 10, which illustrates a typical hand-controlled installation unsupercharged.

The effects resulting from the addition of constant-boost control to such an installation are indicated approximately by moving the throttle lever to maintain a constant boost value throughout the movements of the constant-speed control.

It will be apparent in the diagrams that, within the range of constant-

speed control, boost and power are both affected to some extent by movement of either control, but that revolutions respond only to movement of the constant-speed control.

Variations of load resulting from changes in the flying attitude of the aeroplane are, of course, compensated automatically by alteration of the pitch of the airscrew blades within all reasonable angles of climb or glide.

(A) Ground Run

When the governor is set to give governed r.p.m. for take-off of, say, 2,400, whilst the airscrew is set to give 2,350 static r.p.m. (at chocks) as described in an earlier paragraph, the airscrew is in effect in positive fine pitch when the throttle is in take-off position, and a movement of the throttle will show on the tachometer, so that the switches may be tried with the constant-speed lever in the fully forward position, i.e. take-off position, and the throttle wide open, giving in this case 2,350 r.p.m.

As the aeroplane gathers speed in the take-off, the r.p.m. will increase to 2,400, at which speed the governor will ensure that the r.p.m. are maintained.

Before take-off, the operation of the constant-speed control should be checked. This may be done by moving the cockpit control from the take-off towards the coarse-pitch position and noting the change in r.p.m. Care should be taken that the constant-speed control lever is not moved into the *fully* coarse position during this operation, as this will labour the engine unduly. Half or less of the travel of the lever is sufficient to obtain a good indication on the tachometer that the airscrew is operating correctly.

(B) Take-off and Climb

The constant-speed cockpit control is moved forward to the take-off position. As the aeroplane increases from zero speed, at the start of the take-off, towards flying speed and as the throttle opening is increased, the engine r.p.m. will increase until it reaches the r.p.m. for which the constant-speed unit has been set. From this point on, the r.p.m. will be held constant by the governing action of the unit. This means that full power is available during take-off and climb without excessive engine speed. In the case of engines which give take-off r.p.m. at the chocks, this last remark will not apply, as the governor will be controlling at take-off revolutions from the commencement of the take-off run.

Soon after take-off, it is generally desirable to reduce both the manifold pressure and the r.p.m. The manifold pressure for take-off in a non-supercharged engine is very near the maximum allowed by the engine manufacturer, and since it would increase if the r.p.m. were decreased, the logical sequence is to reduce the manifold pressure first (throttle) and then the r.p.m. (constant-speed lever).

In supercharged engines, changes of manifold pressure following

variations of r.p.m. are largely compensated by the corresponding changes of speed in the blower, and as it is now common practice to fit automatic boost control to such engines, the adjustment as may be required of the manifold pressure at take-off is less urgent and less involved.

All movements of the throttle and constant-speed cockpit control should be made slowly.

(C) Cruising

Once the r.p.m. have been adjusted to the desired tachometer reading, it will be held constant by the governor. Since changes in the aeroplane's attitude and altitude, as well as changes in the engine's manifold pressure, can be made without affecting the r.p.m., it is recommended that if any changes in the cruising r.p.m. or manifold pressure are desired, the r.p.m. be first set and then the manifold pressure be changed. This is a reversal of the second paragraph in (B), but it will be appreciated that, in setting the constant-speed lever to the correct cruising r.p.m., a slight change in boost will occur, so that it is necessary to make the final adjustment on the throttle.

(D) Power Descent

One of the main advantages of the constant-speed control is that it permits power descent without overspeeding of the engine. The unit compensates for the increased airspeed of the descent by increasing the airscrew blade angles.

The only limits imposed on constant r.p.m. are the mechanical limits to the airscrew pitch range. An increase in altitude or an increase in the airspeed requires a coarser blade pitch if the r.p.m. are to remain constant. As the airspeed increases in the descent, the unit will move the blades to a coarser pitch to hold the r.p.m. at the desired value. If the coarse-pitch limit of the airscrew will permit the blades to assume a pitch sufficiently high to compensate for the increased airspeed, the r.p.m. will remain constant. If, however, the descent is too rapid or is being made from a high altitude, the coarse-pitch limit of the blades may not be sufficient to hold the r.p.m. constant, and the airscrew will be unable to accommodate the increase in speed by a corresponding increase in blade angle. Should this occur, the r.p.m. will be responsive to any change in the airspeed or throttle setting in similar manner to the fixed-pitch airscrew.

Since an increase in r.p.m., a decrease in manifold pressure or a decrease in airspeed requires a decrease in blade angle, it is possible, when the blades have touched their coarse-pitch stops, to bring them back under the governing action of the constant-speed control by increasing the r.p.m. setting, decreasing the manifold[1] pressure, or decreasing the airspeed.

[1] For supercharged engines the normal procedure in a power descent will be to maintain cruising boost as nearly as possible whilst reducing the engine speed to a low governed rate of r.p.m.

(E) Approach and Landing

As the manifold pressure and airspeed are reduced in the approach, the airscrew blades will be moved to a finer pitch. When the conditions of manifold pressure and airspeed are such as to require a blade pitch lower than the fine-pitch stops permit, the constant-speed control will become ineffective.

Whilst it is usual to set the two-pitch airscrew control for take-off r.p.m. during approach, in order to have full power available in emergency, this technique is not recommended in constant-speed installations, since intermediate pitches are available and a high effective thrust can be obtained from the airscrew without overspeeding the engine.

Most pilots will prefer to feel the aeroplane respond immediately to short bursts of the throttle during approach, and by coming in under a little power with the constant-speed lever set at, or slightly above, cruising r.p.m., a much more effective control can be maintained.

On landing, the constant-speed control should be set for take-off r.p.m. This causes the blades to move to the full fine pitch, and affords better control in taxying and also permits more satisfactory operation of the engine.

(F) Stopping the Engine

Before stopping the engine, the airscrew should be moved to the coarse-pitch position where the piston is within reach of the piston spanner and the piston leathers, etc., are more conveniently situated for routine inspection.

It is also an advantage to expel as much oil as possible from the cylinder, as the viscosity increases very rapidly as the oil cools, until in really cold weather it may congeal to such an extent as to retard seriously the flow of oil through the ports of the governor.

Until warm oil has replaced the cold oil in the cylinder, therefore, the airscrew will not respond promptly to governor control.

(G) Engine-out Performance

If, for any reason, one engine should become inoperative, the airscrew on the idle engine should be placed in full coarse pitch, in which position it has less drag. This is important, because the engine-out performance of some of our modern aeroplanes is based on the assumption that the airscrew is in this position. In addition, the ceiling is considerably improved for engine-out performance and control of the aeroplane is also much improved.

AIRSCREWS

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